LEARNING AgriCultures

Insights from sustainable small-scale farming

MODULE 2

Soil and Water Systems

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Please note:
This module is the first edition.
We welcome comments and suggestions for improvement.

This publication forms part of the **Learning AgriCultures** series for educators, providing insights on sustainable small-scale agriculture.

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Summary of this module

Soil and water are fundamental elements in agricultural systems. How much land and water there is available, and the quality of the soil and water, are major factors that influence whether farms are productive or not.

This module discusses soil and water as systems. Certain principles about soil and water systems are common to all farms – such as how nutrient cycles and soil food webs work. Similarly, how water enters the farm and the dynamics of soil moisture follow the same principles everywhere. At the same time, there is a huge variety of soil types and climates around the world. A farmer who lives in a floodplain in Bangladesh needs a different type of management option to one living in dry regions like the Sahel or in the Middle East. People who live in the highlands or in the valleys, or on mountain slopes all have different issues to contend with. While we cannot represent all different situations, this module covers a variety of cases of small-scale farming in different regions for students to develop insights into soil and water sustainability.

The module also discusses socio-cultural, ecological, economic and political aspects of small-scale farmers' contexts and how they affect their choices and decisions about soil and water management. Students learn in this module about how farmers can make the most of their soil and water systems to allow for greater farm sustainability.

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Guide to educators

PURPOSES OF MODULE 2

Figure 1: Educators, the target group of Learning AgriCultures

For educators:
- to use a systems approach to teaching about sustainable soil and water processes with special attention to small-scale farmers.

For students:
- to understand the importance of soil and water processes as part of a system;
- to learn about how soil and water systems can become more sustainable for small-scale farming.

How to teach Module 2

Based on testing, about 16 contact hours will be needed to teach this entire module. This does not include time for conducting interviews with farmers, as well as time students spend on assignments. Obviously educators will need to decide for themselves whether to use the entire module or parts of it when making their lesson plans.

The total time required and duration of each lesson will vary depending on the level of the students, the knowledge of the educator, and how many games and assignments you choose to include in the course. An important component is to visit and interview a farmer – for students to understand the practical realities of farming systems.

What is in Module 2

This module is the second one in the Learning AgriCultures series. Module 2 includes three Learning Blocks and a section with Educational Resources. The three Learning Blocks follow the basic structure and systems' approach of all modules in Learning AgriCultures. The blocks build up information on the module's theme according to: The farm system → The larger context → Sustainability and governance of the entire system. The final section with Educational resources contains support material for educators to make the lessons more insightful and practical.

Specifically, the content of this module is as follows:

LEARNING BLOCK 1:
Soil and water processes as part of farm systems

This section gives a closeup view of soil and water as systems in and of themselves, and as part of the farm system.

LEARNING BLOCK 2:
Relating soil and water systems to the wider context

Four issues are presented that have great impact on soil and water systems around the world: Access to land and other resources, changing land and water management practices, and climate variability and climate change. These issues are presented, relating to the four dimensions of the context (socio-cultural, economic, ecological and political).

LEARNING BLOCK 3:
Toward more sustainable soil and water systems

In this section, we provide ideas on how soil and water systems can become more sustainable, how different kinds of buffers can be established and built up in the farming system. This learning also makes the link to governance issues and possible enabling policies as they relate to soil and water systems.

Figure 2: Symbol to indicate link to Educational resources (below) or suggested questions (above)

EDUCATIONAL RESOURCES:

This section contains support material for educators to stimulate deeper insights and discussions in-class and as assignments. Throughout the main texts, boxes of suggested links to resources (see list below) and to probing questions are indicated by the symbols found in Figure 2.

- ***Games:*** for in-class, to help deepen understanding of soil and water systems;
- ***Cases:*** suggestions for further reading and assignments based on articles from ileia's magazine archive, to expose students to different practical examples of methods farmers use, and stimulate discussion;
- ***Photographs:*** for in-class, these can help get discussions going with students on the practical implications of different issues raised in the module;
- ***Videos:*** for in-class, to complement the teachings with visual examples from around the world;
- ***Farmer interview:*** suggested visit with a small-scale farmer, checklist and further on-farm exercises for students; and
- ***Further references:*** suggestions for other freely available books and articles, interesting websites and videos.

Glossary for the whole series

This is separate to the module and includes definitions for difficult terms for the whole Learning AgriCultures series.

LEARNING BLOCK 1

Soil and water processes as part of farm systems

Photo: *Chetha Organic Organization, India*

What do we mean when we talk about soil or water as systems? And how do they interact with one another? What does this mean for farmers and the sustainability of their farms? This block focuses on processes at the farm level, first introducing the main ecological aspects of soil, water, and on their interaction as soil moisture. We will move beyond the farm level in the subsequent blocks.

1.1 Introduction

Whether we realise it or not, soil affects each of us in our everyday lives. Besides being fundamental to the production of our food and other agricultural products, the soil performs a wide range of functions that go beyond farming. It regulates water, sustains plant and animal life, recycles organic wastes, recycles nutrients, stores carbon, filters out pollutants, and serves as a physical support for structures. For farmers, understanding the functioning of the soils on their farms - and how to make the best use of the water available - form the base of their livelihoods. In this block, attention is given to particular aspects of soil and water processes, as well as practices that farmers use to improve the sustainability of their farms.

1.2 Systems thinking about the soil

1.2.1 What is soil?

When we refer to soil, we talk about the earth that is lying above the rock surface. Soils form from the weathering of rocks (the soil's so-called "parent material"), over a long period of time. This weathering occurs because of mechanical forces (physical disintegration of rock because of e.g. water, ice and air movement, as well as activities of plants, animals and people) or chemical forces (decomposition of rock, chemically altering the parent material). Soils vary from being a few millimetres deep – in the case of very young soils or soils eroded by external forces (such as from water, wind or human activities) – to several metres deep. Soil consists of several distinct layers (or "soil horizons"), all of which have their own characteristics. All of these soil horizons together form a distinct "soil profile" (see Figure 3).

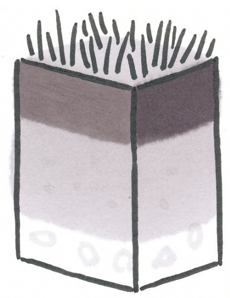

Figure 3: Soil profile showing three distinct layers

Farmers need to understand the soil on their farms very well in order to make the most of it for the growth of their plants and livestock. Around the world, farmers have different ways of explaining how their soils function. For example, they have their own terms and concepts such as temperature, colour and texture, to distinguish between soil types. It is important to understand farmers' views on their soil in order to see how to support them in improving their practices. Below, we focus on the scientific interpretation and terminology to explain soil.

Although they vary greatly from place to place, all soils include five different basic components that are essential to life:

- *Organic Matter:* non-living material coming from decaying plants and animals. Organic matter usually takes up only a small proportion (usually between 1 to 6 percent) of the soil. The quality of the soil's organic matter has a fundamentally important impact on plant growth.
- *Soil biota:* the living and largely invisible part of the soil, made up of soil micro-organisms such as bacteria and fungi, as well as soil animals such as worms and insects. The biota form a soil "food web" as shown below in Figure 6).
- *Soil Minerals:* these take up about half of the soil volume. The mineral elements exist as different-sized soil particles, classified (from large to small size) as sand, silt and clay, of which clay has the greatest capacity to hold nutrients.

These elements are essential to plant growth, as explained below in sub-section 1.2.2 on the soil's nutrient system. The connection between the mineral and organic components of soil systems is very close, as we will see in Figure 5 below.

- ***Water***: the amount of water or moisture present in soils varies greatly between soil systems and also over time, but on average it takes up about a quarter of soil volume. The capacity of soils to retain moisture also varies but greatly determines farm productivity. Soil moisture gets more attention under section 1.2 on Systems thinking about water below.
- ***Air:*** this contains oxygen, hydrogen, nitrogen and carbon in gaseous forms. These are essential for plant growth.

Use the **Soil Game** (R1.1) to help students understand these five components of soils.

Soil classification

While these are the basic elements of soils all over the world, huge variations in soil types can be found even over short distances. This is so because of different conditions under which they have developed: variations in climate; the rock material that the soil has developed from; the different activities of plants, animals and people; the topography of the terrain (e.g. whether it is on a slope or in a valley); and how old the soil is (time). While farmers have different ways of classifying the soils they work with, many attempts have been made to distinguish soil types around the world, according to specific characteristics. A general way of classifying soils is according to their textures, or the size of their main soil particles: *sand* is the largest size, *clay* is the finest particle size and *silt* is in-between). Classifications are typically named for the primary constituent particle size or a combination of the most abundant particle sizes, e.g. "sandy clay" or "silty clay." A fourth term, *loam*, is used to describe a roughly equal concentration of sand, silt, and clay, and leads to the naming of even more classifications, e.g. "clay loam" or "silt loam."

Another main distinguishing characteristic for soil classification is climatic zone. *Humid tropical* climates in general have high temperatures and rainfall, leading to deep, strongly weathered and leached soils with low nutrient contents. In the tropics, lush vegetation is almost the only source for replenishing nutrients. *Arid tropical climates* have low precipitation and high evaporation rates, and therefore give rise to soils that contain variable amounts of easily soluble components, such as calcium carbonate, which is left behind after evaporation of water from the soil; this may 'cement' the soil and reduce infiltration capacities. In *temperate climates*, soil formation is more or less restricted to the warmer part of the year, resulting in less weathered and shallower soils when compared to tropical regions. In the sub-arctic and northern temperate regions, major changes in the past have had an interesting effect on the present soil distribution; there, large glaciers during the Ice Ages removed all soil material, and so new soils started forming only after the retreat of the ice. Consequently, soils of these regions are relatively young and "immature". In arctic climates, soil formation is restricted to an even shorter time of the year than in temperate regions; arctic soils are also strongly influenced by freeze-thaw processes and the presence of a permanently frozen sub-soil known as "permafrost".

1.2.2 The soil's nutrient system

All soils include different chemical elements that are important to the survival of plants. Of these, 16 elements are essential for plant growth, though some are needed in greater quantity than others. These are:

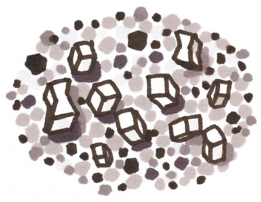

Figure 4: Inorganic nutrient store in "soil solution"

- ***The three "building blocks" that form about 96% of plant dry matter:*** hydrogen, oxygen and carbon; these come mainly from air and water, though as Box 2 shows, carbon in the soil is a very important element of soil organic matter, for various reasons;
- ***Thirteen nutrients:*** plants need large quantities of "macro-nutrients" to build up protein and for the good functioning of all living cells (primarily nitrogen, phosphorus and potassium; and secondarily calcium, magnesium and sulphur); and smaller quantities of "micro-nutrients" (boron, copper, iron, chloride, manganese, molybdenum and zinc). Even though plants need fewer micro-nutrients, they are still important for good growth.

Nutrients mainly come from the soil, from decomposing plant residues, animal remains, soil minerals, organic manures or compost, and soil micro-organisms; but they also come from the application of inorganic fertilizers; nitrogen-fixation by micro-organisms in conjunction with roots; gases from the atmosphere; or from nutrient-rich sediments deposited through erosion and flooding. But just as too small amounts of nutrients cause weak growth, too much can also cause harm to plants, as well as polluting waterways when leached out of the soil. Leaching of nutrients such as nitrogen is one of the main problems that arises when applying inorganic fertilizers to the soil as they allow for an immediately available supply of specific nutrients, which may not all be able to be taken up by the plants. Box 1 provides a very brief overview of the importance of the different elements to plant growth. Our intention is to provide a systems' approach to soils, and we will not go into biochemical details (find further references under Educational Resources).

Nutrient uptake

Nutrients are taken up by plants through the roots. For most nutrients, the presence of water makes it easier to take them up, particularly for Nitrogen. Good water management in the soil is therefore very important for plant growth – we will talk more about importance of soil moisture in section 1.3, on Systems thinking about water.

In general, for plants to be able to absorb essential nutrients from the soil, the nutrients must be in soluble, inorganic form. They must therefore be converted, or mineralised, from organic to inorganic form to be able to be taken up into the roots (see Inorganic pool in Figure 5: Soil nutrient cycle). Many different organisms in the soil play a role in breaking down materials and making nutrients more or less available to plants as well (see sub-section 1.2.3 on Soil food web). Note that commercial fertilizer application does not need to be converted as it is immediately available in its inorganic form.

Box 1: Brief overview of the 16 elements necessary for plant growth

Elements	Important functions and roles in plants
Hydrogen (H)	Necessary for building sugars and building the plant; comes almost entirely from water (H_2O)
Oxygen (O)	Necessary for cellular respiration; comes from carbon dioxide (CO_2 - carbon and oxygen) and water (H_2O- hydrogen and oxygen)
Carbon (C)	Backbone of many plants' organic molecules; is part of the carbohydrates that store energy in plants (also see Box 2 below for special significance of Soil Organic Carbon (SOC))
Macronutrients	
Nitrogen (N)	An essential component of all proteins; photosynthesis
Phosphorus (P)	Important for plant growth and flower/seed formation; Energy storage/transfer, root growth, straw strength, disease resistance.
Potassium (K)	Regulates the opening and closing of the stoma, important for regulating water; reduces water loss from leaves and increases drought tolerance; crop disease resistance
Calcium (Ca)	Important constituent of cell walls, regulates transport of other nutrients into the plant and is also involved in the activation of certain plant enzymes
Magnesium (Mg)	Among other roles, this is an important part of chlorophyll, a critical plant pigment important in photosynthesis
Sulphur (S)	Structural component of some amino acids and vitamins, and is essential in the manufacturing of chloroplasts (green pigments which are necessary for photosynthesis)
Micronutrients	
Boron (B)	Important in sugar transport, cell division, and synthesising certain enzymes
Copper (Cu)	Necessary for proper photosynthesis, involved in many enzyme processes and in the making of lignin
Iron (Fe)	Necessary for photosynthesis and respiration
Chloride (Cl)	Important in the opening and closing of stomata; also plays a role in photosynthesis (specifically for splitting water)
Manganese (Mn)	Necessary for building chloroplasts, for photosynthesis; enzyme function
Molybdenum (Mo)	Helps enzymes in building amino acids; legume N-fixation
Zinc (Z)	Required in a large number of enzymes

Nutrient losses

Nutrients that get taken up by plants will be removed for harvesting or feeding of animals, which leads to nutrient losses from the soil. Nutrients can also be lost directly from the soil - through erosion and runoff (by water and wind), leaching (water that percolates through the soil, carrying dissolved nutrients downward beyond the reach of roots); and direct losses of gaseous forms of nutrients (e.g. nitrogen and sulphur) into the air (volatilisation). Nutrient losses are further increased when removing crops from the farm, and when their residues are not returned to the land. Nutrient losses are not only costly and wasteful, but they can be a source of environmental contamination when they reach lakes, rivers, and groundwater.

Use the **Diet-Soil nutrient Game** (R1.2) to get a discussion started with your students by comparing main soil nutrients to the local diet.

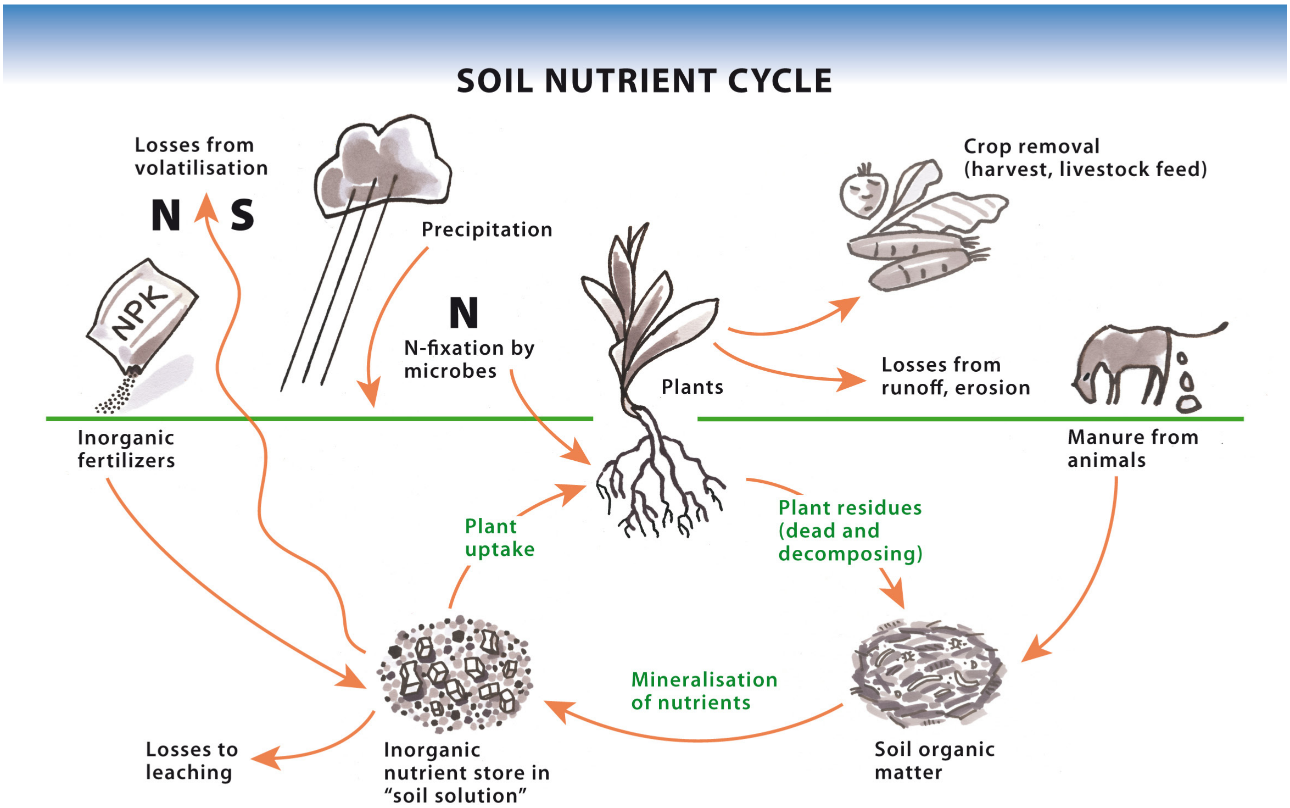

Figure 5: Soil nutrient cycle

- Considering the characteristics of soils in temperate as compared to tropical regions, how will these differences affect the nutrient cycles in each region?
- There are mini-nutrient cycles within the larger cycle as well. For instance, when crops are fed to animals, and later the manure is returned to the soil. Can you think of other ways nutrients can be recycled in the soil system?

Soil nutrient cycle

Natural processes constantly change nutrients from one form to another. It is this continuous process of biological-geological-chemical transformations, that we call the "Soil Nutrient Cycle" – see Figure 5. Please note that the cycle as it is represented is a simplification of reality, in order to make it easier to understand the various processes going on simultaneously in the soil. For example, the two pools representing soil organic and inorganic nutrients, do not really exist as isolated "pools" in the soil. All these processes, including their rates (speeds) are very dynamic, changing over time and place.

1.2.3 Soil Food Web: importance of a "living soil"

Besides being a physical substrate, soil is also a living entity or system in itself, containing an enormous number of organisms, and vast biodiversity. One gram of good soil contains millions of organisms, including several thousand different species. They range in size from the tiniest one-celled bacteria, algae, fungi and protozoa, to the more complex nematodes and arthropods, to the visible earthworms, termites, insects, small vertebrates and plants. This community of

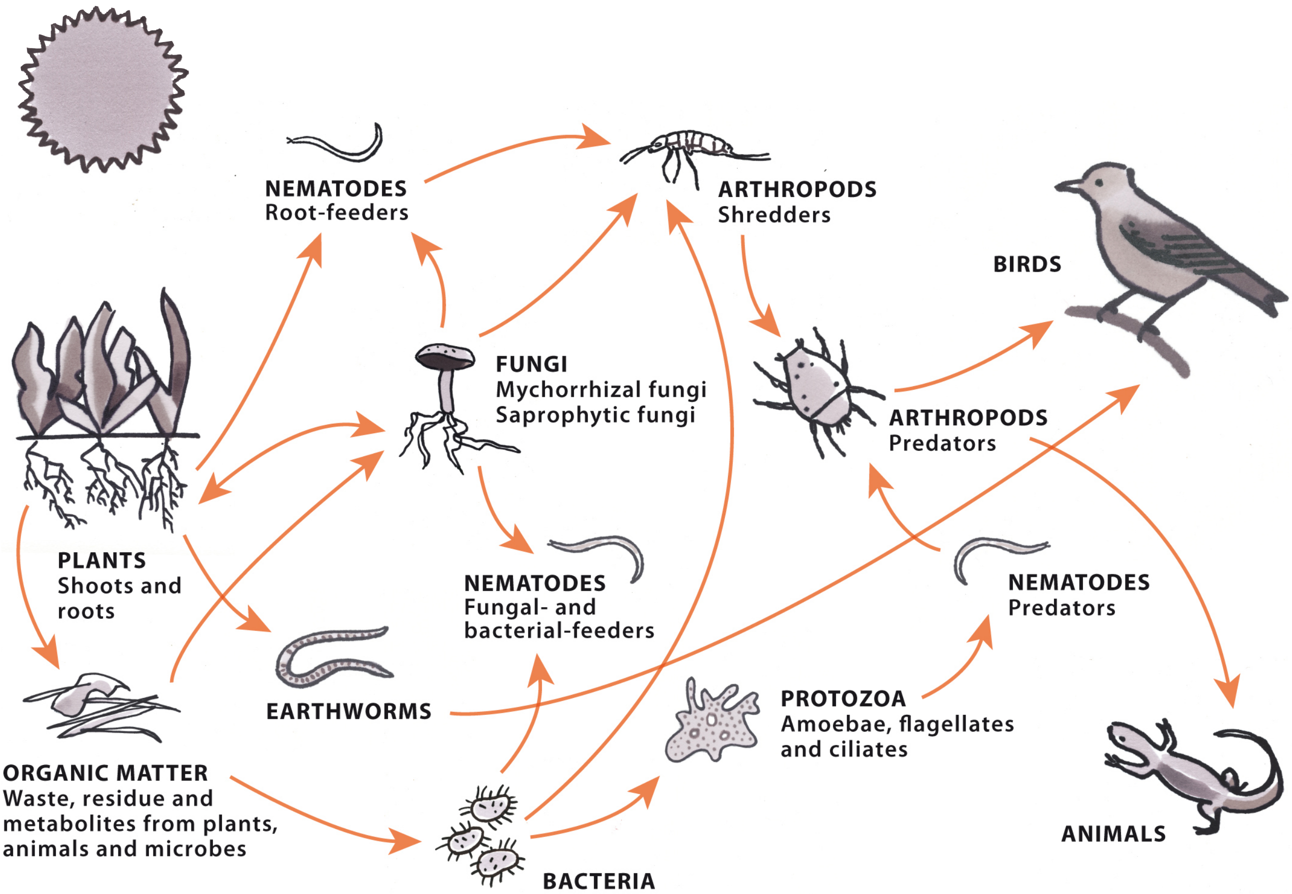

Figure 6: Soil food web (modified from Soil Food Web, Inc. www.soilfoodweb.com)

organisms makes up a "soil food web" densely packed in the upper layers of the soil (see Figure 6 below). These organisms can be divided into different levels of producers and consumers that interact and convert energy and nutrients between themselves, as well as in association with plants' roots.

Although much about soil ecosystems is still unknown, what we do know is that soil organisms modify the soil environment, affecting its physical, chemical and biological properties and processes. It is the soil organisms that interact with minerals and organic matter, helping to create soil structure and therefore affecting water infiltration, drainage and holding capacity. For example, earthworms create tunnels and burrows throughout the soil. Activities in the soil determine plants' access to nutrients through decomposition of rocks, organic matter, animals and micro-organisms. Roots absorb these minerals if they are readily available in soil solution.

Most micro-organisms (or "microbes") are commensalists, but some have mutualistic (beneficial) or parasitic (working against, e.g. causing disease) relationships with plants. Examples of how microbes work with plants are: making nutrients available for plant uptake, and contributing to protection against insect pests, microbial parasites and diseases. An important example of a mutualistic relationship is that of mycorrhizal fungi that are able to infect plant roots and

- What happens to nutrients when burning land?
  In many parts of the world, widespread dry-season burning of vegetation is practised as a quick, labour-saving method to clear land and prevent weed/pest infestations, as well as for other reasons such as for hunting. (Go to Article R.2.2)

thereby assist in nutrient uptake. A special family of plants called legumes form root nodules in which rhizobia (bacteria) enhance the absorption of nitrogen and its transformation within the roots (we will go more into this subject in Module 3). In temperate areas, blue-green algae contribute to nitrogen fixation. Other examples of important services from microbes include the degrading of pollutants such as pesticides and petroleum derivatives, and the fixing of greenhouse gases like methane and carbon dioxide.

Feeding soils to build up soil organic matter

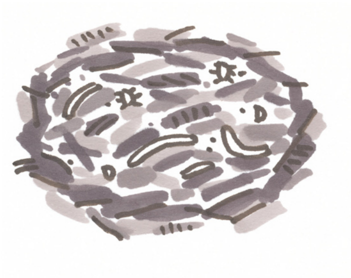

Figure 7: Soil Organic Matter provides important nutrients

Although all soils have different characteristics, one thing that is clear is that practices that *build up* rather than deplete the soil organic matter – and work with the soil's living processes - are essential. For instance, failing to keep recycling nutrients from organic materials like compost or residues to the soil, can deplete organic matter. Also, while farmers commonly till the soil to loosen it, prepare the seedbed, and control weeds and pests, tillage also breaks up the soil structure, can destroy the habitat of helpful organisms, speeds up decomposition, and increases the threats of erosion and compaction if not carefully managed.

Practices such as burning and deforestation, without replenishing the soil, also lead to degradation. With time, farmers notice that their soils get "tired" due to loss of soil organic matter, their yields decline, and erosive processes become accelerated. These soils are more vulnerable to environmental forces such as wind erosion and flooding, with a greater risk of desertification. It also leads to less biomass being available to replenish the soil nutrients. For poor soils with

Box 2: Special significance of soil organic carbon as part of soil organic matter

The soil's organic carbon (SOC) content comprises an important part of soil organic matter (SOM). SOC is valued by agrarians as a natural buffer for soil, insulating it from extreme changes in temperature, reinforcing soil structure, reducing compaction, improving water-holding and drainage, storing nutrients and providing energy for soil biological communities.

Carbon cycle

Plants absorb carbon from the atmosphere. They then transfer it to the soil through their roots, or as decomposing plant residues. Soil carbon may be returned to the atmosphere from the soil, when the organic material in which it is held is oxidised by decomposition or burning.

SOC is even more widely appreciated now, because it is seen as a potential reservoir for carbon dioxide (CO_2), a greenhouse gas. The amount of carbon in the soil is much larger than in the atmosphere (3.3 times) and in vegetation (4.5 times). As a result, soil carbon is seen as one of the major reservoirs for the global carbon pool.

How land is used and managed determines whether the soil can be a "source" or "sink" for atmospheric CO_2. Agricultural practices that build up rather than deplete soil organic matter (and thus also SOC) therefore take on greater significance. Not only does this help to buffer/reduce the effects of water shortages, drought, nutrient depletion, and salinity, but it can also help mitigate greenhouse gas emissions.

little organic matter to replenish nutrients, inorganic fertilizers can provide the necessary nutrients to be able to get good production. Nutrients from fertilizers are immediately available for plant uptake and do not depend on conversion processes.

In Box 2, we give special attention to soil organic carbon as an important part of the soil's organic matter buffer.

1.2.4 Practices to build up soil organic matter and nutrient buffers

Small-scale farmers work in many ways towards building up nutrient pools in the soil, some of wich are described in this section. Compare different types of farming practices that you would find in your region. Think about how different agricultural practices in your region build up rather than deplete soil organic matter. What practices would be relevant to your region in order to improve soil nutrient availability?

Figure 8: crop residues can be used for mulching

Mulching

Mulching can be done with a variety of materials – hay, leaves, manure, wood, bark, cocoa hulls, rice straw, peanut hulls, and even plastics and "geotextiles". The type of material used depends on what is available, and what effect is desired. For example, using plastics and other slow to degrade materials will decreas loss of moisture to evaporation, rather than adding nutrients to the soil. Advantages of mulching are the reduction of evaporation, suppression of weeds, the insulation of soil against extreme heat and cold, the prevention of soil compaction and control of wind and soil erosion. Mulching has a number of disadvantages too. Some mulches inhibit water penetration or may attract rodents, insects or slugs. Also, it is not always easy to find materials to use as mulch, and may require more labour to collect and distribute. Many farmers also prefer to use crop residues for fodder, fuel or as construction material rather than leaving them on the soil.

Using cover crops and green manures

Cover crops and green manures (cover crops that fix nitrogen or concentrate phosphorus) can help maintain soil fertility, safeguard against erosion, and control weeds. This practice has similar issues to intercropping (see below), and often farmers are more interested in it if the cover crop can support food or fodder production, lead to a cash crop, and/or if it is shown to control weeds. When selecting the type of crop, farmers need to take into account that the crop not attract pests and disease, and should have multiple uses. An important principle for Conservation Agriculture is to always keep the soil covered as well as minimising disturbance (tillage) of it, in order to build up the nutrient buffer and minimise erosion.

Figure 9: collecting and composting manure is good for the soil's nutrient pool

Applying manure or compost

Compost and composted manure are useful for the organic matter buffer, increasing the pool of nutrients in the soil, and improving its capacity to retain water and reduce moisture loss to the atmosphere. In spite of its usefulness, the process of developing compost and applying it requires careful management and increased labour costs. In Module 4, we will be going more deeply into the issue of livestock and the use of manure in farming. In resource-poor areas, this practice may be difficult as it means that farmers cannot use residues and manure for other needs such as for fuel or animal fodder.

Applying inorganic fertilizer

Particularly in degraded land, the nutrient pool in the soil may be so deficient that it is necessary to use chemical fertilizers, at least to kickstart crop growth. Once enough biomass is produced, it will be possible to cycle organic matter into the soil and build up the buffer for the long term. Fertilizer is easy to apply but it is costly and therefore out of the reach of many small-scale farmers, requiring fertilizer subsidy programmes.

Diversifying cropping systems, intercropping and using crop rotations

Having a mix of crops and crop varieties, rather than depending on stands of sole crop varieties, and also rotating crops from season to season will help to buffer the nutrient cycle in the soil (e.g. selecting species that fix nitrogen within the mix, intercropping with crops that supplement nutrient deficiencies, etc.). Having different harvesting times will help to protect the soil from erosion because it will not be bare all at once (e.g. mixing perennial crops with annual crops). This subject will be further explored in Module 3: Cropping systems.

Intensification through improved fallows

In many traditional systems, leaving land to fallow for some years has been an important way to increase the nutrient pool in the soil. However, as population pressure grows, it is imperative to develop sustainable ways to use land more intensively. "Improved fallows" mixes the best of traditional ideas with more intensive land use.

Using trees

Trees help to safeguard the soil from accelerated erosion and compaction. Their deeper root structures loosen the soil to increase water infiltration, and can reach nutrients and water in the lower part of the soil horizon. Trees can be used in buffer and contour strips in sloping areas, and as part of agroforestry mixes. Forests are very important for ensuring the supply of water in watersheds. Trees can also be used as windbreaks which reduce the drying action of the wind, thereby delaying evaporation of soil moisture. Tree shade also reduces exposure to sunlight and hence the drying of the top millimetres of soils. This can be particularly important for preserving morning dew. Although they have many benefits, a balance must be maintained, particularly in mixed farms, so that the trees and agricultural crops do not compete for nutrients and water to the detriment of the crops.

What do farmers around the world do to build up their soil nutrient buffers? These articles describe experiences with mulches, cover crops and green manures, conservation agriculture, composting, inorganic fertilizer, improved fallows and using trees.
(Go to Article Pack R.2.3)

Reducing and ultimately eliminating use of herbicides and pesticides

Herbicides and pesticides may be necessary when weeds and crop pests and diseases escalate to an extent that other methods are not possible. However, they also kill beneficial soil organisms and can harm farmers and their families, especially when not managed professionally. Integrated pest management (IPM) offers alternatives and a way of building up a buffer in the farm to stave off pests and diseases. This subject will be further explored in Module 3: Crop systems.

1.3 Systems thinking about water

1.3.1 Importance of soil moisture

Figure 10: Moisture in the soil, essential for plant growth

While the soil system is fundamental to the growth of living things, water is one of the most important components of plant growth. Moisture in the soil determines crop growth and agricultural production. The germination of seeds and root development depend on water availability. Crop yields fall drastically if a crop is stressed, even to the point that additional water that lifts a crop out of the stressed zone may more than double its yields. Ample soil moisture storage also makes it possible to overcome dry spells in critical growing stages and hence secure good yields even when rainfall is erratic or falling outside the season. On the other hand if, soil moisture falls below a crop's wilting point, crop losses will be irretrievable. Soil moisture is critical to soil chemical processes. Particularly nitrogen-fixation depends on water availability in the soil and hence soil moisture can contribute substantially to the availability of nutrients.

Soil moisture retention and infiltration capacities

Soil moisture also depends very much on the nature of the soil itself. In general, clay, silty and sandy soils all have different capacities to retain soil moisture: clays have the highest "moisture retention capacity" (i.e., the capacity of the soil to hold onto water), while sandy soils have the least. The presence of adequate organic matter greatly improves the soil's moisture retention capacity. Particularly in semi-arid areas, the use of compost or organic manure makes all the difference and effectively can reduce the need for irrigation.

At the same time, it is important for water to be able to be absorbed into the soil, and not be lost as runoff or evaporation. This is referred to as the soil's "infiltration capacity". Soil will have less infiltration capacity and more water losses if it is left bare and with an even surface, particularly on sloping land. The faster the flow of water, the more runoff will occur, which can lead to accelerated erosion as well. It is therefore important to enhance the percolation of water into the soil by slowing down its flow over the land, by making barriers such as with stone bunds, vegetation strips, walls, terraces and other structures or by preparing land ahead of the rainy season – so that it can absorb rain and runoff. Another factor to keep in mind is that less infiltration will occur if the surface is allowed to harden and become compacted. This happens when land is over-grazed by livestock, or machinery and heavy equipment is repeatedly used. Some soils, such as the fine-grained clays, are particularly susceptible to compaction.

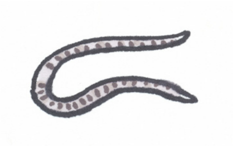

Figure 11: Earthworms help loosen soil, to increase water infiltration

Several other aspects are important in determining soil moisture. One is the burrowing action of earthworms and other animals in the soil food web (see Figure 6 above). Worms, beetles and other insects and crustaceans loosen up the soil and increase its infiltration capacity, and hence its ability "to make more of rainfall" and to also better distribute soil moisture over the soil profiles.

Figure 12 below shows soil moisture within a systems' perspective. The actual soil moisture available in the soil is the result of several factors. The first is the composition of the soil: clayey and loamy soils will retain water well – but sandy soil does not and dries out quickly. The second factor that determines the soil moisture is the organic matter in the soil – more organic matter means a larger capacity to retain water. The third factor is the amount of water applied to the land – obviously actual soil moisture is very much related to this. The final factor regards the different soil water management practices used; depending on the local climate and soils there are several practices that may help improve and retain soil moisture.

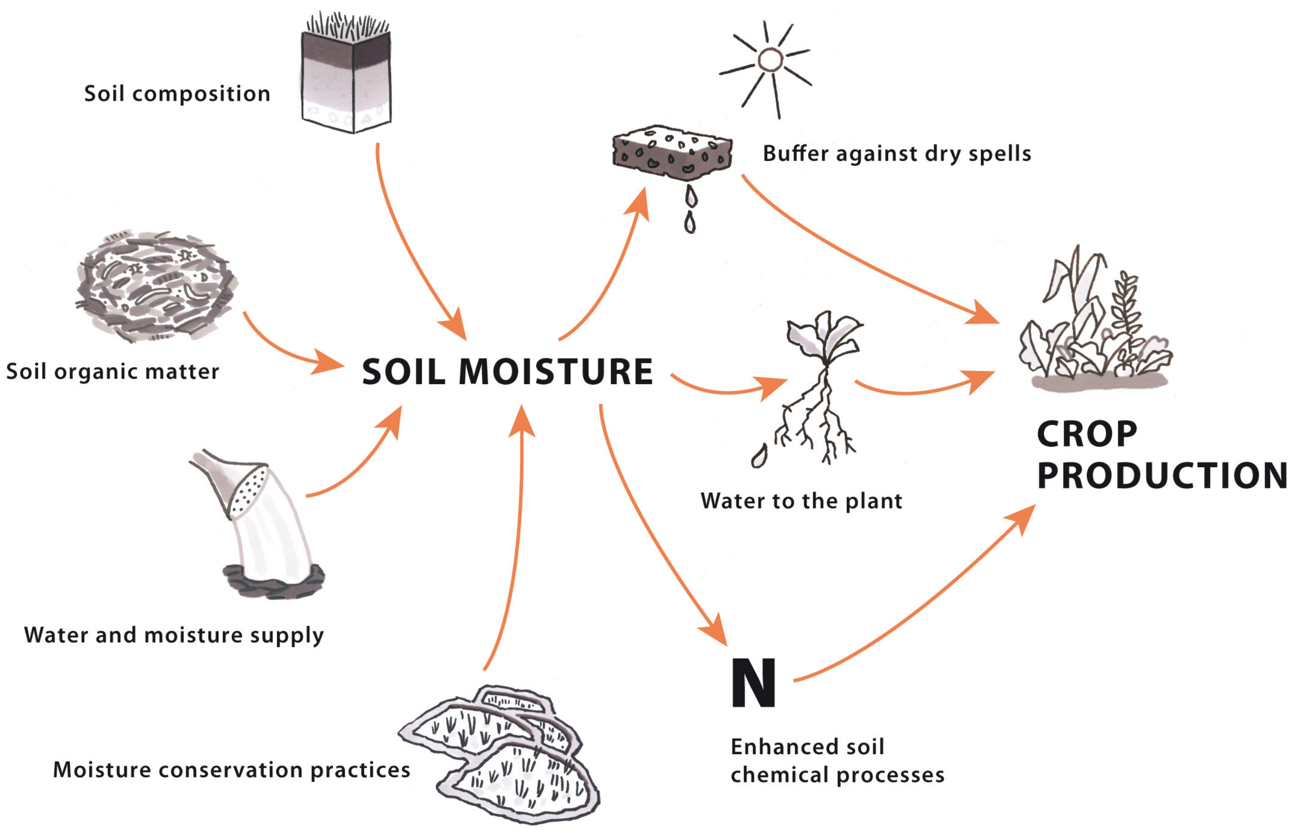

Figure 12: Soil moisture as a system

Figure 12 also shows how soil moisture in its turn has a strong influence on crop production. It does so through several routes: adequate soil moisture provides a buffer and ensures water availability to plants even in the absence of rainfall; soil moisture is essential to mobilise transport of nutrients to and through the plants; and adequate soil moisture improves soil chemical processes and aids the availability in particular of the macro-nutrient, nitrogen.

The challenge is not only to increase the availability of water to the land – but also to retain the moisture within the soil. As discussed earlier clay and silty soils have a better capacity to retain moisture. Increasing the organic content of the soil further improves this. Cultivation practices can also improve the retention of soil moisture in the soil – for example, mulching (to avoid evaporation from the soil surface) or deep ploughing (moving moisture to deeper layers), though the appropriateness of such practices are location-specific.

1.3.2 Practices to build up soil moisture and erosion control buffers

Farmers work in many ways towards sustaining their soil moisture system. Some are described in this section. Compare different types of farming practices that you would find in your region. Think about how different agricultural practices in your region build up rather than deplete soil moisture. What practices deplete soil moisture, and how do these need to change?

Improved tillage

Tillage (or ploughing) is a very important practice used by farmers around the world. Tillage helps to loosen soils, clears the land of weeds and other unwanted debris, and increases the possibility for water infiltration, which can be essential in rain-dependent agriculture. Deep ploughing in particular helps to break the plough plan – which otherwise makes it difficult for water to percolate throughout the soil. Ploughing also helps to move moisture-rich soil deeper down and preserve the moisture for the growing season. Closely related to this is the practice of 'planking' – closing the soil pores with the help of a plank or beam dragged across the soil by a tractor or by bullocks. This practice blocks evaporation of water from the soil and slows down soil drying. In some areas in the past even fine sand was used to stop soil moisture evaporation.

Figure 13: Tillage helps loosen soils, clear weeds, and conserve moisture, but can lead to increased erosion if not done properly.

However, tillage can also increase soil erosion when vegetation does not quickly grow once the rains start, especially on steeply sloping land. In some places, farmers have decided to reduce their tillage, sometimes even eliminating it (called no-till or zero-till) in order to reduce the risk of accelerated soil erosion, enhance the maintenance of soil organic matter and reduce the evaporation of soil moisture. This is not always possible and can lead to increased soil compaction, water-logging and increased weed competition in for example, clay-poor and structurally weak soils found in (semi-)arid areas. In some cases, it is necessary to continue repeated ploughing in order to improve infiltration, minimise runoff and to reduce evaporation. How farmers adapt their practices depends on their soil's characteristics, as well as social traditions and availability of resources, for example, crop residues for mulching (see section 1.1.4).

Box 3: What is conservation tillage?

Soil scientists and water scientists both refer to "conservation tillage" as a good practice; however, this concept seems to mean different things depending on who is talking. Soil scientists seek conservation of nutrients, while water scientists primarily seek water conservation. For soil scientists, this means tillage that keeps a certain percentage of the soil surface covered with crop residue mulching or cover crops – which means minimising tillage. For water scientists, conservation tillage (also called "green water" management) refers to tillage methods that allow for maximal possibility of water percolating into the soil. It can even mean deep-ploughing in order to move moisture-rich soil to lower layers and avoid evaporation from the surface.

What do farmers around the world do to build up their soil moisture buffers? Experiences with terraces, contour bunds and ridges, as well as rainwater retention practices are the subject of these articles. (See Article Pack R2.4)

Using in-field water conservation structures

There is a wide range of techniques that farmers use to improve the soil moisture availability in their fields. By making obstructions (e.g. strips of vegetation, building walls across slopes) or creating ways to trap water in their fields, farmers slow down surface runoff and erosion, accelerate infiltration and increase soil moisture. Examples include: eyebrow terraces, trenches/ deep furrows, contour soil/ stone bunds, contour bund terraces, semi circular bunds, trapezoidal bunds, trash lines, vegetative bunds (for instance vetiver strips), zai planting pits, inter-row systems, contour ridges, tied furrows, negarim micro-catchments.

Levelling and closing of ruts and gullies

Soil loses its capacity to retain moisture once it is affected by deep drains and gullies, caused by uncontrolled flooding and sheetflow. Levelling the land and closing ruts and gullies will contribute to a better distribution of water over the land and a better retention of moisture.

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LEARNING BLOCK 2

Relating soil and water systems to the wider context

Photo: *Rik Thijssens, Indonesia*

While farmers work hard to improve their soil and water systems, there are many factors outside their farms that affect the health of these systems. While farmers can keep adapting soil and water management practices on their farms, how do conditions in their wider context open up opportunities or impose limitations on what they can do?

2.1 Introduction

In the first learning block, we looked at water management at the level of the farm system. Farmers can do a lot to increase their yields through improving the retention of soil moisture and nutrients as well as avoiding erosion in their management practices. However, factors such as how water is supplied to the farm, climate change and variability, access issues regarding resources such as land, nutrients and water, and the need to intensify practices also have an impact on farmers' ability to manage their farms sustainably. This learning block discusses soil and water systems within the wider context in which small-scale farmers operate.

2.2 Managing water in the context of watersheds

A photo gallery is presented in the Educational resources section that can help stimulate discussion with your students about different aspects (ecological, economical, socio-cultural and political) in the context. Go to R3. Be sure to supplement the learning material with relevant images, stories and references from your own region.

Water enters the farm in a number of ways:

- *Rainfall (and other precipitation):* rainfall originates from evaporation - mainly from the sea, but also from in-land resources. The type of rainfall determines how much of it will be absorbed in the soil, and how much will continue as runoff or river flows: the more intense the rainfall the less is absorbed in the soil;
- *Diversion of water by way of irrigation*: using either surface water sources from rivers and lakes or groundwater, raised by pumps. A special form of agricultural water supply concerns flood-based systems where floods either temporarily inundate river plains or are diverted to adjacent land;
- *Moisture from the water table:* for soil moisture, this is largely a factor of shallow groundwater tables. If the groundwater table is high and close to the surface, it will add substantial moisture to the upper soil layers. Obviously if is too high, water-logging can be a problem. There are in fact many interactions within the water cycle between groundwater, surface water, and sub-surface groundwater flows and these need to be well understood. The low flows in rivers during the dry season for instance mainly come from shallow groundwater that is slowly released to the river bodies. In rainy periods, the reverse is true and groundwater systems get recharged from the high river flows; and
- *Dew:* in a limited number of areas, dew is an important source of soil moisture – for instance in areas around lakes and reservoirs or in areas where moist air from the sea is forced up mountain escarpments. Depending on the air humidity, dew forms at a certain temperature (the so-called "dew point"). The availability of dew is increased for instance by stones in the soil (that cool off below the dew point). In some areas shade trees are used to prolong the availability of dew in the morning and postpone its evaporation.

The relative importance of all of these different sources of moisture greatly depends on where a farm lies within a larger-scale system called a "watershed". The higher the farm lies, and the steeper the slopes, the more a farmer needs to take measures to ensure against the erosive effects of runoff, and to increase infiltration. Simply put, a watershed refers to an area of land where all of the water that is flowing over or under it drains into the same place (see Figure 14). It includes rain, snow

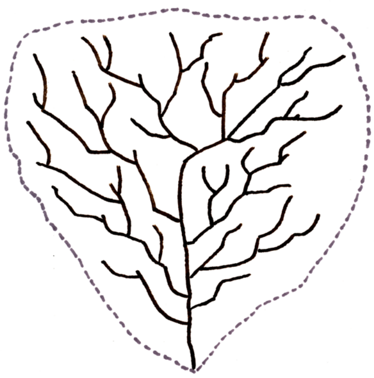


Figure 14: example of water flowing in a watershed

melt, streams and rivers, lakes, ponds and wetlands. A watershed is separated from adjacent watersheds by a geographical barrier such as a hill or a mountain, which is known as a "water divide". Watersheds drain into larger basins in a hierarchical pattern, with different watersheds combining into one larger river basin. The term "river basin" is usually used for the larger geographic units.

Hydrological cycle at watershed level

All of the water flows described above form part of a large-scale hydrological cycle. Most hydrological processes take place within the boundaries of a watershed, and even groundwater in shallow aquifers usually conforms to these boundaries. In Figure 15, an overview is provided of the most important hydrological processes in the water cycle within a watershed.

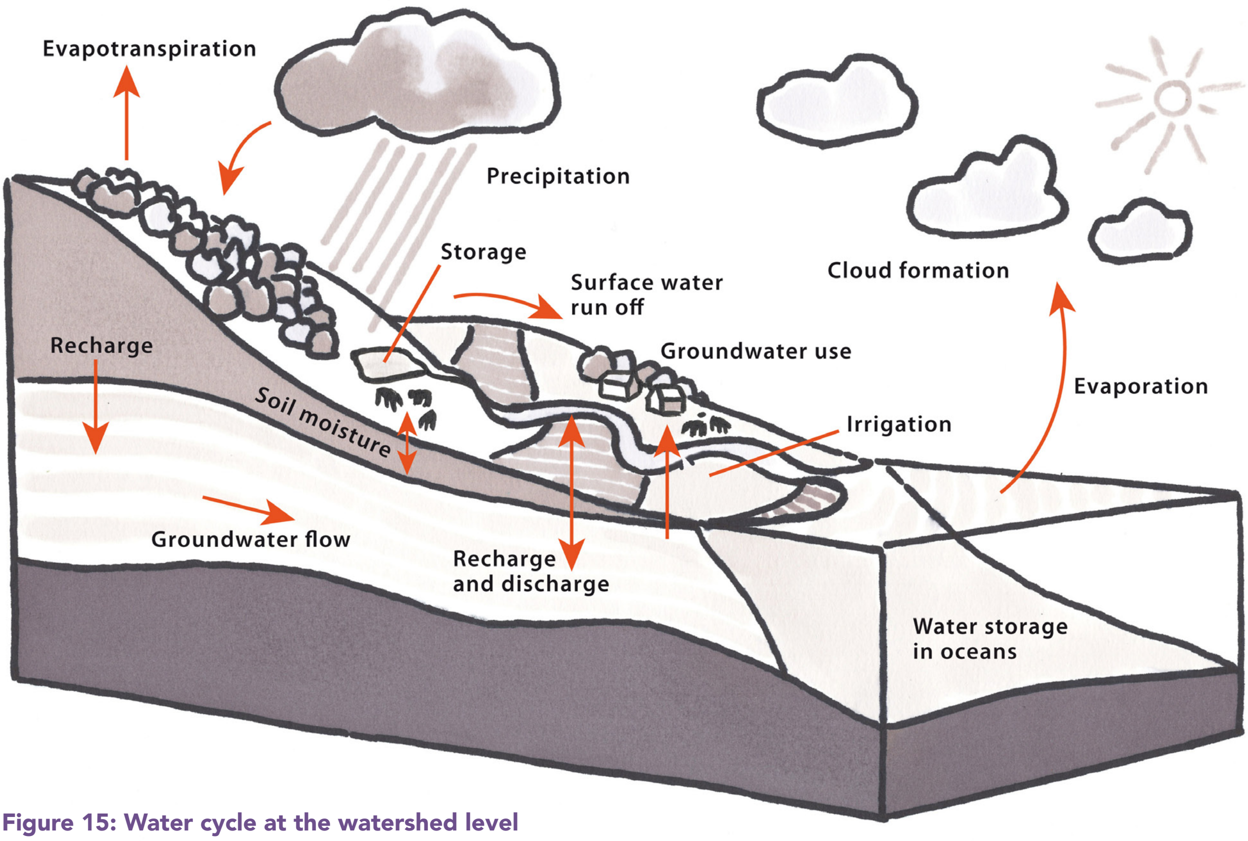


Figure 15: Water cycle at the watershed level

2.3 Responding to climate variability and change

There has always been variability in climatic episodes, such as droughts, storms and flooding – and farmers have learnt to cope with this variability. They adapt their practices throughout the season, carefully responding to changes in rainfall and seasons through their selection of crops, crop varieties, planting and other cultural measures, while at the same time changing how they manage their soil and water systems. This so-called "response farming" reflects an approach that seeks resilience and flexibility in farming – and sustainability.

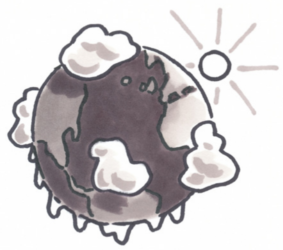


Figure 16: Global warming adds to climate variability

Because of global warming, it is projected that more frequent and intense heat waves, storms, flooding and drought will take place, adding to the climate variability that is already there. These changes are predicted to be felt differently in different regions – some places will become wetter, others drier. It is foreseen that tropical regions will experience more unpredictable growing conditions, including more intense rainfall events between prolonged dry periods as well as reduced or more variable water resources. Another likely effect is the change in the rainy seasons, which are so important in different parts of the world: these may become more erratic - start later and with longer dry spells.

How can farmers help to mitigate climate change and at the same time build up their soil organic matter buffer? One idea is Biochar production. (Go to Article R2.5)

Because of this, farmers need to pay even more attention to creating natural buffers in their soil and water systems, in order to be able to adapt more easily to and protect themselves against shocks and stresses introduced by climate variability. At the farm level, managing soil moisture for instance will become even more important. At the watershed level, managing the functioning of water buffers (in terms of soil moisture, shallow groundwater and local surface storage) in the area becomes imperative. The next section explains this subject in greater detail.

2.3.1 Managing water buffers

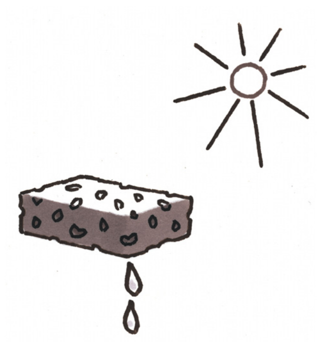


Figure 17: Water buffer

Improving water buffers in a watershed can be done through three processes: *recharge, reuse and retention* (3R). ***Recharge*** adds water to the groundwater buffer and as such it adds water to its circulation. Recharge can come from the interception of rain and runoff water (natural recharge), from increased infiltration of natural processes by human interventions or it can be the welcome by-product of, for instance, inefficient irrigation or leaking pipes in water supply systems. In order to encourage recharge at a higher level therefore requires managing natural recharge, applying artificial recharge and controlling incidental recharge.

Retention slows down the lateral flow of groundwater. This helps “pond up” groundwater and creates a large wet buffer in the subsoil. In fact, within a watershed there may be areas with a wet buffer and areas with dry buffers. The large advantage with wet buffer areas is that it is much easier to retrieve water from these than from dry buffers. In such conditions, it is easier to retrieve and circulate water. Retention therefore makes it possible to extend the circulation of water. In this way, the groundwater table is also raised. Slowing down or even controlling the lateral outflow of the water table affects soil moisture and soil chemistry and improves yields of rain-dependent agriculture. Some argue that it is better in certain cases to control soil moisture from below than to provide surface irrigation water from above because of lower losses through evaporation and less development of salt crusts on the topsoil.

Reuse is the third element in buffer management and is a large challenge. Water scarcity is not only resolved by managing demand through reducing its use, but also by keeping as much water as possible in active circulation. Reducing the evaporation of water is important as water that evaporates "leaves" the system and can no longer circulate in it. The second important process in managing reuse is managing the quality of the water. The possibility for reuse depends on the quality of the water – with different functions putting different demands on the water quality.

Figure 18 provides an overview of the range of techniques to improve water buffers in a watershed through stimulating the 3Rs. Which technique is chosen depends on the ecological conditions of the watershed (i.e, humid or arid, urban or rural, and type of groundwater and surface water system) - as well as context issues such as economic limitations and political will. As shown in the figure, examples include subsurface dams in river beds, sand storage dams, local surface water harvesting ponds, dune and river bank infiltration, gully plugs to control local deep drainage, controlled drainage, compartmentalised road planning and more.

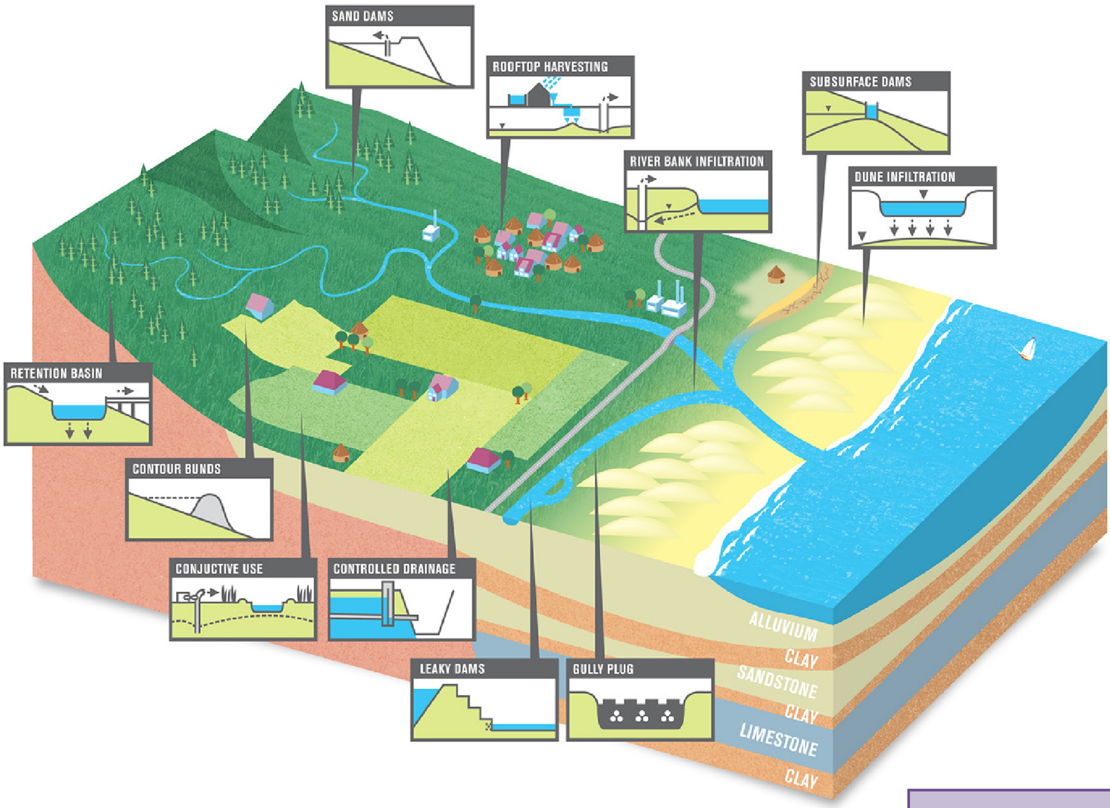


Figure 18: Representation of a water basin showing different technical interventions that contribute to improving water buffers (from van Steenbergen & Tuinhof, p.5)

- Do you know about examples of different water buffers established in your region?
- What kinds of practices could small-scale farmers in your region realistically implement?
- What kinds of practices should local government or others implement?

2.4 Adopting more intensive farming practices

2.4.1 Technological approach to intensification

Agriculture takes up an important part of land use: over one-third of the world's land base is being used for livestock and crop production. Also, over 70 percent of today's human water use is for agriculture. At the same time, populations around the world are rising, and food security has become an increasingly urgent issue. How to meet the food needs of all people has long been a discussion in the world of agricultural policy-makers. It was this question that propelled the development and wide-scale extension of "modern" agriculture techniques starting with the Green Revolution that began in 1945. This technological approach (see Figure 20) is based on input packages designed by agricultural research centres that include "improved" high-yielding seed varieties together with chemical inputs (pesticides, herbicides and fertilizers) and better irrigation - all with the aim of developing more intensive agriculture.

These modern farming practices have undoubtedly increased agricultural production around the world, allowing for greater access to more - and more varied - food (and other) products. In many areas, it has by-passed rainfed farming. As higher yields were the primary objective of this technological approach, its objective was reached. However, as explained in Module 1, these advances have had some unintended negative effects as well.

Figure 19: Different aspects of the technological approach of modern agriculture

In general, small-scale farmers have benefited less, as the technological approach favours wealthier and larger-scale farm enterprises. For instance, these technologies need to be bought and not everyone has ready access to cash. This approach has moreover created a situation in which people are dependent on the market for their inputs such as seeds, soil amendments and biocides, and therefore they need to keep making enough money to be able to keep paying for them. While some manage to keep up with this, others have fallen into debt. Also, in some places men have benefited more than women, thus deepening disparities. In addition, the introduction of input packages has brought down the value placed on local knowledge and traditional agricultural systems, which are based on a balance between mixed crops and livestock. There have also been ecological problems, many of which relate to soil and water systems. These include an increase in pollution from chemical inputs, loss of wildlife biodiversity, as well as soil compaction and overcommitment of water resources due to the use of heavy machinery and intensive irrigation, for instance.

2.4.2 Access to land and other resources

For all farmers, a fundamental question in their farm management decisions is their access to land and water resources – as well as the quality of these resources. In some places, having access to land is so important it is a part of people's identity, and its value goes beyond money. How much access they get depends on social factors such as population pressure and social norms on who gets priority (e.g. men or women, particular social groups and minorities), economic factors (e.g. whether you can pay for access), ecological factors (e.g. water quality, whether there are forests or other ecologically rich resources in the area), and political factors (e.g. rights and laws regarding ownership and use).

Figure 20: Population change has led to the need for more clarity on rights to land

Especially where population pressure is high, rural families have been squeezed, moving onto smaller and smaller land bases, and to more marginal land (e.g. on steep slopes, into forests). Some lose land, have landless children, and others work land composed of small pieces scattered over a community. Besides this, communal land is coming under threat and more conflicts can emerge between farmers, between farmers and pastoralists, with people living in forests, or even with urban developments. In many places, population change has also led to a shift in the social mix of farmers, as the most able-bodied and often the men leave to find work elsewhere. This can lead to a "feminisation of agriculture", meaning that more farms are being headed by women. It has also led to agriculture in many places being taken over by an aging population.

Rights of access

Whether a farmer has secure access (as tenure/ownership, long-term usufruct or other variation) over land is a very important factor in how s/he manages the farm. When access to land is not secure, farmers may make decisions that give as much profit as possible in the short term - and therefore do not think about investing in efforts that promote long-term sustainability in which profits come later. For example, farmers with insecure land tenure tend not to plant trees on their land – as they are not sure they will have the benefit of them. If access to local forests is not clearly assigned, it is likely that people will cut down trees and harvest other profitable forest products to help ensure their families' survival. Future ecological and economic benefits of trees will then be lost.

How easy is it for woman to get acces to land in your region? Go to Article R2.6 for a look at women and land access in Rwanda.

Farmers' (secure) access to land and resources – as individuals or members of a local community - is greatly determined by official laws, rights and rules extended by the government. As well, rights are determined by socio-cultural rules especially where traditional systems still have a strong influence. Informally, social norms such as whether women, cultural minorities or other groups have fair access to land and other resources also have a major influence on those groups having access to them. Another issue occurs when land is cultivated by tenants who do not have a lasting claim on the land, or when land is officially owned by the State, which is at liberty to take land titles away and open up areas for new settlers, for instance.

Figure 21: Land-grabbing from small farmers without compensations occurs easily in situations of poor governance.

Small-scale farmers and vulnerable groups of course are greatly affected where fair rules and good governance do not exist. In this situation, the phenomenon of "land-grabbing" becomes easier. In other words, the rights to fertile agricultural land can become extended to large-scale enterprises and to cities that are expanding, at the cost of small-scale and poor farmers, and in many societies women farmers in particular lose out.

2.4.3 Intensifying land management practices sustainably

If they manage their resources well, and are supported in their efforts (see Learning Block 3), small-scale farmers can intensify their land management practices in a beneficial way. As there is more pressure on the land and water resources, more care needs to be taken to manage these resources efficiently. This happens for instance with the construction of terraces on hillsides and other erosion control measures, which is often triggered by land scarcity. Another example of better management is the use of efficient field irrigation methods as water becomes scarcer (see section on Irrigation below).

As land becomes more intensively used, more attention needs to be made to the adequate recycling of soil nutrients and land management in general. The greater pressure on the land may also trigger better land management, for example stimulating more attention to terracing and erosion control measures to compensate for the reduced per capita availability of land. Funds generated by family members working in cities may also be used to invest in improved land management. If well managed, more intensive techniques like leguminous (tree) crops or fertilizers, and better use and conservation of moisture in the soil can increase the possibility of enhancing production in poor soils.

- Looking at your region, what is the situation of small-scale farmers and access to land? Is this an important issue there?
- Can you find examples of intensive land-use practices affecting soil and water systems? (e.g. do farmers include fallow periods? Are cropping patterns changing?
- Can you find examples of farmers adopting modern farming practices? What is the result for small and large-scale farmers?

Intensification approaches should seek ways to combine good management of "modern" agriculture with sound locally specific knowledge. This could be, for example, on mixing of different varieties, local buffering mechanisms to avoid soil nutrient depletion, methods to improve water infiltration capacity, as well as traditional ways to deal with erosion or water-sharing. Co-operating at a watershed level is imperative if all farmers in the area are to benefit from good soil and water conservation practices.

One example of an intensive approach integrating different techniques can be found in "Integrated Soil Fertility Management" (ISFM). ISFM aims to replenish soil nutrient pools, maximise on-farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of "modern" inputs. It makes use of both local/traditional and scientific knowledge to find the technologies that best fit farmers' resource management needs. Examples of ways to improve nutrient efficiencies include use of green manures and legumes, animal manure, mineral fertilisers, composting, crop rotation, improved fallows, agroforestry, improved germplasm and biomass transfers. For more information on ISFM, see the Tropical Soil Biology and Fertility programme website under Further references (R6).

2.4.4 Irrigation systems for small-scale farmers

Improving use of irrigation has been very much stimulated by "modern" agriculture programmes. While irrigation practices have long been used by farmers, having more access to water through large-scale irrigation projects has boosted production around the world. Irrigation system developments have improved the uncertainties common in rainfed agriculture – bridging dry periods and making it possible to grow high water-demand crops. This development has however not been without problems, some of which are similar to those described in the section above. Wealthier farmers have enjoyed more benefits than poorer farmers, and new (in some areas, severe) environmental problems have emerged, because of badly managed irrigation programmes: water-logging triggered by over-irrigation, the drying up of downstream areas – including productive wetlands and grazing areas, depletion of and falling groundwater tables in some areas, as well as salinisation of the upper soil layers and the spread of certain diseases (e.g. malaria, bilharzia).

Figure 22: Small-scale irrigation system using furrows in the field

In this sub-section, we will look more in-depth at irrigation programmes, and examples of how small-scale farmers can benefit from them. Irrigation systems come in many different forms, using different sources of water, channelling water differently, and they range from small- to large-scale. There are three main categories of irrigation, all of which are relevant to small-scale farmers: surface irrigation, groundwater irrigation and flood-based farming systems.

Surface irrigation

Surface irrigation diverts water from rivers, lakes and springs by gravity, to the irrigated area. The area served by the irrigation canal system is called the "command area" – but with water shortage not all of it may actually be irrigated. The size of a single command area may vary from a few hectares to over one million hectares. The smaller systems are often farmer-built and farmer-managed, whereas the larger systems usually involve a separate, usually public, management agency – with farmers still responsible for the water distribution at the field level. There are several ways to distribute water within an irrigation command area. In some areas there is a clear "on demand" element, which makes it possible for farmers to influence the time and volume of water they receive at their farm. In other systems, such flexibility is missing. In these surface irrigation systems an important issue is the duration of the irrigation cycle – the time that it takes between two irrigation turns. If this is very long it becomes difficult to grow crops that require regular watering, such as vegetables.

Another important factor in understanding irrigation systems is the irrigation duty: the amount of irrigation water available per hectare. Obviously this needs to be seen in relation to other sources of water that are available at different times of the year: rainfall, run-off water, groundwater and even dew, but particularly in arid areas irrigation water may be the main source of water in the important crop seasons. There are several main approaches to the distribution of water in an irrigation command. One is so-called 'protective irrigation'. Here surface irrigation is spread thinly – the objective being to provide protective water supply and prevent crop failure over a large area. In such systems, the irrigation duty is low and there tends to be much competition for water between upstream and downstream farmers. In other areas, irrigation duties are higher and shortage is not a constant factor. High irrigation duties also increase the risk of water-logging, however. In water-logging, water levels in irrigation systems have risen so much that they saturate the root zones of the plants. Many plants cannot grow under such circumstances. Rice is a major exception, although the success of the so-called SRI (System of Rice Intensification) programmes suggests that rice yields will be higher, if the paddy fields are not water-logged (see Box 4).

Different examples with irrigation for small-scale farming exist around the world: improving irrigation practices, groundwater irrigation and a specific flood-based irrigation practice called spate irrigation (Go to Article pack R2.7)

Box 4: System of Rice Intensification (SRI) and efficient use of water

SRI is a set of rice cultivation practices that aim at higher production and lower consumption of water. The practices were first developed in the early 1980s in Madagascar, but have since then spread throughout the world. In SRI, rice seedlings are transplanted early – i.e. within 8 days. The transplanting is done in carefully prepared squares to make weeding easier. In SRI, irrigation is provided intermittently, i.e. every 2-3 days. As a result, the roots of the rice plant develop much more under SRI than under conventional systems. Normally, inundating the paddy also serves to control weed growth, but the philosophy of SRI is that water is too costly to just use as a herbicide. Under SRI, more labour is required for weeding and for removing paddy plants. Botanical herbicides are used. Results differ but are very positive across the board. Water savings of more than 20% are common and yields are usually 10-30% higher.

Groundwater irrigation

While water is delivered through gravity canals in surface irrigation, water in groundwater irrigation water is pumped. This can be done with manual devices (treadle pumps, rope pumps and traditional lifting devices) or mechanical pumps. At shallow depths – up to 7 metres, centrifugal pumps are common. Beyond this depth, other types of pumps, in particular submersible pumps, are commonly used. Using groundwater for irrigation makes it possible to carry out “precision water” supply – using water exactly when it is required by crops. In surface irrigation, this is not always possible as an individual farmer often cannot change the timing of water delivery to his or her farm. In fact, groundwater irrigation has increased tremendously and has very much been promoted by the Green Revolution, which some argue even made it possible. These days, most water in many large-scale surface irrigation systems comes from (shallow) groundwater. This is called “conjunctive” use in which excess surface water ends up as shallow groundwater and is as such reused. In principle, this combined use of surface and shallow groundwater can bring the best of both worlds: surface irrigation water that is not used ends up as shallow groundwater and is reused; the groundwater component makes it possible for water to be applied to the crops at the time when it is most required and the regular surface supplies make sure the shallow groundwater levels stay intact. In Box 5, water-use efficiency in small irrigation systems is discussed further.

Box 5: Micro-irrigation and water-use efficiency

Particularly in areas where water is scarce, there is a constant quest for irrigation to become more and more efficient: use less water to produce the same crop. Several micro-irrigation methods have gained considerable popularity over the last fifteen years – in particular *drip irrigation* systems and *sprinklers*. In drip irrigation, small openings in a network of water tubes delivers small drips of water 'at the doorstep' of the crop. Drip systems are often used in horticultural crops – especially in tree crops. Sometimes a so-called "fertigation" tank is connected to the network of drip lines – adding fertilizer to the irrigation supplies directly. Sprinkler systems are more common in field crops – they consist of "rain guns" spreading water evenly over the farmland.

Farmers are often attracted to these efficient irrigation methods for reasons other than water-use efficiency. For instance, sprinkler systems spread water equally over the land, thereby reducing the risk of fungi. Drip systems also sometimes produce better quality fruit – as crops are not stressed in vital stages of fruit setting. Also, drip systems are considered easy to use, as farmers do not have to check whether water is obstructed in the field channels. There is a *caveat* to the water-use efficiency of micro-irrigation systems though. The efficiency of micro-irrigation systems means that there is little water left over. However, such excess water is not necessarily lost – but instead may infiltrate and be reused later as groundwater. In fact, in some areas micro-irrigation has gone hand in hand with an expansion of irrigated areas – beyond what is sustainably available in the concerned watershed.

Flood-based irrigation

The third type of irrigation systems concerns flood-based farming. Here, flood water is used to moisten the land and grow crops. There are several forms of flood-based farming systems. One is recession agriculture, in which flood plains or lake banks are inundated during the rainy season and crops are planted as the water recedes. A variation on this concerns inundation canals that branch out of a river and start to flow only if water levels in the river have reached a certain level. Another form of flood-based farming is spate irrigation, which is common in semi-arid areas. In spate irrigation short-term floods are diverted and spread over a land area – for irrigation, rangeland regeneration, filling drinking water ponds or recharge.

What kinds of irrigation systems do you know about that work well for small farmers in your region?

2.5 Sources for this learning block

- Ileia. 2003. **Editorial: Access to and control over resources**. LEISA Magazine 19 (3): 4-5.

- van Steenbergen, Frank and Tuinhof, Albert. 2009. **Managing the water buffer for development and climate change adaptation: groundwater recharge, retention, reuse and rainwater storage**. ISBN: 978-90-79658-03-9 (www.bebuffered.com)

- Tittonell, Pablo, Michael Misiko and Isaac Ekise. 2008. **Talking soil science with farmers.** LEISA Magazine 24 (2): 9-11.

LEARNING BLOCK 3

Toward more sustainable soil and water systems

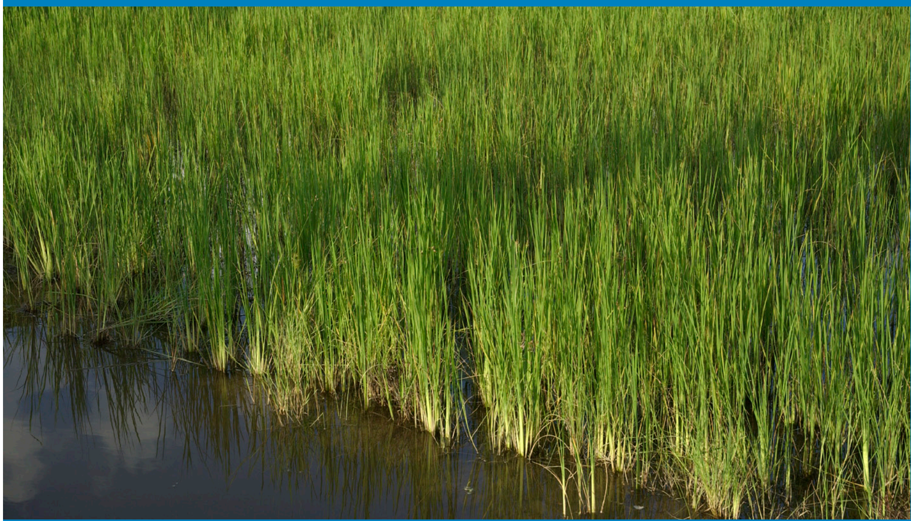


Photo: *Folkert Rinkema*

What do we need to make soil and water systems more sustainable? How can management practices be improved when thinking about different challenges coming up in the context of small-scale farming? What kinds of land and water policies would be possible, in order to promote and support small-scale farmers' sustainable approaches and livelihood efforts?

3.1 Introduction

This learning block reviews what we mean by sustainability of small-scale farming. This is followed by a more in-depth look at what this means for soil and water systems in terms of four aspects, namely ecological, socio-cultural, economic and political sustainability. Working towards an approach of sustainability and managing this approach wherever farms are, require deep reflection and good processes of decision-making. As governance has to do with how decisions are made and implemented, how this important issue relates to greater sustainability of soil and water systems is therefore also discussed in this section.

3.2 Understanding sustainability in terms of soil and water systems

3.2.1 Reviewing what we mean by "Sustainability"

In Module 1, we discussed the concept of sustainability of farming systems. In short, we defined it as an approach in which buffers are built into and strengthened in farming systems, so that farmers can keep adapting to different challenges coming up. For small-scale farmers, who tend to get little support from their governments, these challenges are often compounded by an unpredictable and risky context. Because of their small size and lack of economic power, social and political status - and especially when they live in marginal ecological regions - small-scale farmers need to be very creative and resourceful to be successful.

As introduced in Module 1, sustainable approaches focus on building as much "adaptation" as possible into farming (see Figure 23 below, which comes from the discussion in Module 1). This means that sustainability cannot be thought of as a specific endpoint, but is rather a dynamic process. In this approach, farming is perpetually undergoing a dynamic process of trying to become more sustainable: i.e., different elements keep changing and farmers keep learning how to respond and adapt their strategies to the changes. They keep improving different buffers in their farming systems and make use of diversity to support the adaptability of their farms.

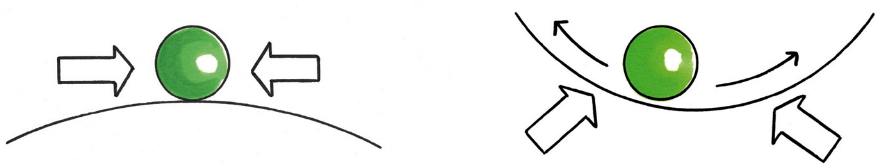


Figure 23: Comparing "control" and "adaptation" approaches

3.2.2 Sustainability approach to soil and water systems

What do we mean by buffers when it comes to sustainable soil and water management practices? In Learning Block 2, different examples of context issues relating to soil and water systems were discussed (watershed management, responding to climate change and climate variability, access to land and resources; and adopting more intensive farming practices). We need to keep these issues in mind when seeking greater sustainability in farming systems. Remember that the ideas as laid out here are general, and therefore more or less important in different locations. The sustainability issues to be focused on will need to be analysed and adapted according to the specific conditions of the farm and community.

3.3 Sustainable soil and water systems for small-scale farmers

In Module 1, we introduced four dimensions of sustainability: the ecological, economic, socio-cultural and political. This section summarises sustainability approaches to soil and water systems, following this organising structure. Examples of how policies can strengthen sustainability approaches are also provided within each sub-section.

3.3.1 Ecological aspects of soil and water sustainability

Figure 24: Managing buffers for ecological sustainability

The state of the natural resource base, the climate and the watershed in which a farm lies, determines to a great extent the ecological boundaries of its soil and water system. For example, how much water – surface and groundwater – as well as how water enters into a farm system is affected by the topography, and vegetative cover, including forests, of its watershed. The climate's precipitation and temperature patterns also affect its soil and water system. On the other hand, farmers' practices also greatly influence the quality of the ecological environment in and around the farm system. For instance, their practices can accelerate or slow down erosive processes; take care not to pollute the water running through their farms; and so on. A balance must therefore be found between using the available resources for good production levels, while taking care to not overstep ecological boundaries.

A sustainability approach calls for the building up of ecological buffers in farming systems. Buffers are needed to allow farms to withstand climatic variability (e.g. too dry or too wet seasons) as well as being able to bounce back quicker after sudden natural calamities, such as flooding or even hurricanes (see article below).

A number of management practices have been described in both the previous learning blocks. Buffers build up the desired resources such as moisture and nutrients, while also taking care to not overstep ecological boundaries within the whole watershed.

- Reflecting on what was discussed in learning blocks 1 and 2, make a list of different ways to build up ecological buffering in soil and water systems in your region.

Policies that can support ecological sustainability

Below follow some examples of policies that can strengthen soil and water systems' ecological sustainability.

Promoting local land and water management

There are several examples of programmes to promote local planning and management of land and water resources by farmers, such as shared canal systems or maintenance of hillside forests. These programmes aim to put sustainable land and water use on the collective agenda and are often complemented by encouraging a better understanding of the resource and its constraints. In many cases, such programmes have been implemented by civil society organisations, including farmer groups – with or without the involvement of local government. The challenge with these programmes is to do them at a larger scale – beyond single communities and to link them to larger land-use planning and water utilisation processes.

- What are different practices farmers have adopted to buffer themselves against big storms and flooding? In India, several examples exist of improving soil and water systems at a watershed level. (Go to Article pack R2.8)

Watershed improvement programmes

Watershed improvement programmes promote a range of measures to control erosion, improve soil moisture and recharge groundwater. In many countries such activities are part of rural employment programmes. This brings a risk, as the work may be implemented without too much concern for the effectiveness of the individual measures – and primarily to generate work opportunities instead. Chances may be lost this way – in particular because of their size, well-planned rural employment programmes make it possible to introduce new useful practices (certain recharge techniques or new ways of composting) on a large scale.

3.3.2 Socio-cultural aspects of soil and water sustainability

Figure 25: Farming sustainably strengthens positive social and cultural factors

Farmers' choice of soil and water management practices and farming decisions is greatly determined by social and cultural factors. The perspective and attitudes that farmers and the wider community hold on water and soil can influence their choices and behaviour. For example, how they view the soil, and their particular management decisions based on rituals or philosophical choices. Some farmers choose to adhere to certain approaches or world views that affect what inputs they find acceptable for the soil (e.g. Biodynamics or Kyusei Nature Farming. Besides this, farmers are often constrained because of cultural norms and values on gender equality, labour division and women's and other social groupings' rights of access to land and other resources. These socio-cultural norms, values and beliefs need to be understood and taken into account when seeking to change practices.

On the other hand, a sustainability approach seeks flexibility and adaptability, and therefore may require people to modify some of their norms and values to adopt more sustainable practices. Many ideas have been discussed in the previous learning blocks, on how to improve soil fertility and soil moisture. Changing practices will probably require different labour patterns (for example, in preparing and applying compost or mulch in different fields) as well as initial investments. They might also interfere with gender roles, and create greater labour imbalances than before. As well, farmers will be more motivated to make efforts toward long-term soil and water gains if they have secure land tenure. Farmers may be more motivated to make efforts to change practices if they can see some immediate benefits for their household – rather than only long-term ecological benefits. For example, if practices or new technologies can help save labour or ensure decision-making power to those using them, they will be more motivated to change their practices. This becomes more complicated when working on water management (erosion and runoff control, irrigation and drainage) within a watershed, as it is an affair that includes the whole community. What individual farmers can do depends on what their neighbours uphill or upstream are doing. We will further discuss the important related issue of Governance in a section below.

Policies that can support socio-cultural sustainability

Below follow some examples of policies that can strengthen soil and water systems' socio-cultural sustainability.

Land tenure policies:

There are several relevant land tenure policies that have a direct impact on land management. One that was mentioned earlier concerns ownership titles. In some countries, land ownership is vested in the State – at least for large areas. This causes a degree of uncertainty for individual land users and farmers who as mentioned above, may be restrained in investing too much effort in land improvement – or for instance in tree planting, as this requires a long-term interest in the land.

A related issue concerns the legal status of community land – and the degree to which this is supported by formal law. This may concern local forest, hill slopes or grazing grounds. It is not unusual for there to be a degree of ambiguity, which can play badly for users who have less economic or political clout, such as small-scale farmers, if official land titles are awarded to outsiders.

A third important land tenure policy concerns land distribution. In countries with individual land titles, there may be legal upper limits to individual ownership. Beyond these limits, land can be redistributed. Such laws are invariably very sensitive and difficult to implement. Large landowners usually have several ploys to mask their real ownership and sometimes manipulate the administration – even adding land to their name rather than losing it.

Special land use policies

In some countries a well-established system of land use planning is in place

Understanding farmer perspectives on sustainability and building on them helps to get farmers to improve soil and water management practices. Examples of land tenure policies in Brazil and the process of introducing by-laws in Zambia show complexities of socio-cultural aspects of sustainability. Go to Article pack R2.9.

Figure 26: Soil and water practices should support farmers' economic sustainability

– making it possible to integrate different investment activities and setting aside certain areas for certain uses. An example is the system of using trees for 'improved fallowing' in Zambia, where fallows were supported by law to allow the regeneration of land. Other examples of land use policies are the protection of groundwater recharge zones – to maximise the infiltration of water and replenish aquifers and protect them from pollution. Similarly in the United States grass strips are promoted around farmland to trap organic and chemical pollutants and prevent that they end up in local rivers.

Promoting soil laboratories

There have been efforts in a number of countries to popularise the use of soil laboratories. This has been done for instance by giving financial support to local entrepreneurs or civil society organisations to open a soil lab facility – and charge farmers a modest fee for the services. In principle, a better understanding of the specific soil characteristics in one's land can lead to substantial savings in fertilizer use for farmers, in practice the business case for such soil laboratories has not been easy.

3.3.3 Economic aspects of soil and water sustainability

The economic situation of farmers and of their wider community also has a large influence on the economic options available to them. The less the farmer has access to cash and the more isolated an area, the less access s/he has to wider marketing facilities as well as opportunities such as borrowing credit. In the short term, these farmers need strategies that depend more on improving their efficient use of locally available natural resources for their soil amendments, and less on bought inputs such as fertilizers and improved seed.

If new practices lead to improved economic resources of farmer households, this gives greater motivation to change or adapt more sustainable soil and water practices. Many cases describe how farmers did not stick to sustainable soil and water practices once project funding stopped because they did not see other benefits such as savings or higher production quickly enough.

Policies that can support economic sustainability

Below follow some examples of policies that can strengthen soil and water systems' economic sustainability.

Water investments

Investments in water control by governments are often substantial – and may take up a large part of the public budget and in cases of very large projects even use extra-budgetary means. In addition, in some countries electricity supply to agricultural pumps is subsidised – again adding up to a considerable expense. The argument in the latter case is whether such sums are not better spent on other activities – for instance, recharge or better soil moisture retention. It is important to understand where water investments are made, to what extent small farmers benefit from these works and whether they make sense. For instance: in some cases it may be better to invest in improved water management at field level than in diverting more water to an area, for instance when most water in a river is already committed.

Subsidies on agricultural inputs

During the Green Revolution fertilizers have often been made available at subsidised rates – to encourage farmers to make a transition to new farming systems. The same has been done with soil amendments – such as the supply of lime in areas with acid soils. Because of the volumes involved, the budgets required for these subsidies became gigantic - in some cases jeopardising public finance. Quality management and adulteration has been another area of concern. In many areas, fertilizer subsidies have been phased out.

There are debates going on as to whether to reinstall such subsidies – especially in Africa. Proponents argue that the non-availability of inorganic fertilizers is an obstacle to food security and agricultural growth. Opponents argue that there are alternatives in better use of integrated farming systems and that subsidised fertilizer use may cause dependencies that in the long run are not sustainable.

With micronutrients the situation is often different. In general, the awareness on the need and the required application of micronutrients is limited – leading to no use or to overuse in some places. The supply chains of micronutrients may also be non-existent and the development of a distribution system is required to address the needs. Setting up agricultural input supply chains can be quite challenging – especially in poor undercapitalised rural areas there may not always be many outlets with sufficient working capital to sell such inputs.

In a project in Vietnam, farmers agreed to change their practices to offset erosion when they could also bring short-term economic gains. Organise a debate between students to represent two views about fertilizer subsidies for small-scale farmers. (Go to Article pack R2.10)

3.3.4 Political aspects of soil and water sustainability

The extent to which political and legal systems help small-scale family farmers or hinder them in their farming, and the extent to which people in charge also protect the rule of law, has a fundamental impact on soil and water systems' sustainability at all levels – from individual to nationwide.

Government policies and safeguarding of laws can help to influence the development of more sustainable soil and water management practices, and discourage irresponsible practices. For example, a fundamental political issue in many parts of the world is rights of access to land, water and other resources. If small-scale farmers, including women and other social groupings (cultural, tribal, religious, caste groupings…) have secure access, they will invest in longer term strategies that are in the interest of sustainable management of soil and water systems.

Figure 27: Governments need to implement and safeguard laws that support sustainable soil and water systems

Government policies can also stimulate specific changes of behaviour. Sustainable practices can be subsidised, such as forest protection, and encouraging controls on use of groundwater, create conservation buffer zones, and discourage uncontrolled burning, deforestation, and pollution of water systems. If applied well, such policies can improve the functioning of soil and water systems, contributing to farm production and sustainable livelihoods. Bad policies on the other hand will have the opposite effect.
There is an important third category of policies as well: those that exist on paper only, yet have no budget to match them, no enforcement mechanism to match them and sometimes no plan to take them forward.

- Can you think of policies that are affecting soil and water management in your area?
- Or of instances in which good laws are not being safeguarded? Why not?
- Can you also think of opportunities for integrating soil and water management into large planning efforts?

Another important element of government policy is the degree to which soil and water management issues are integrated into larger planning systems. For example the construction of roads has a large impact on erosion and on groundwater recharge. If the cross-drainage of mountain roads is not properly taken care of, rainfall runoff may accelerate and concentrate, resulting in erosion. On the other hand, roads may also contribute to water management – if roads are properly located they can slow down and retain sheet flows in heavy rainfall events and cause the water to infiltrate.

Examples of policies that can in principle have a substantial impact on sustainability of soil and water system management were integrated into the preceding sub-sections 3.3.1 to 3.3.3.

3.4 Governance of soil and water sustainability

Figure 28: Good governance means that farmers living in an area can participate in making decisions affecting their soil and water systems.

3.4.1 Revisiting the concept of "Governance"

Simply put, "governance" means "the process of decision-making and the process by which decisions are implemented (or not implemented)". Governance refers to all levels of decision-making – including in the household, local, national or international governance. It refers to all those involved in making and implementing decisions, and therefore goes beyond the government only. "Good governance" means that decisions that affect people – such as small-scale farmers – should also allow them to become involved in the process of decision-making. It also means that farmers should be able to organise themselves so that they can voice their needs and have their rights respected.

In situations of **poor** governance, sustainability will most likely lose out. Lack of consultation processes often leads to decisions that are not to the long-term benefit of the ecological environment. At the same time, small farmers living there may not have a "voice" to stand up for their livelihood needs. There will be little support for their economic systems and little understanding of the different local contexts in which small-scale farming operates. There may in some areas be little interaction and links between farmers in the same area – and even lack of trust – so they will not solve shared problems or present a common position. There may be "silent disasters", whereby their resource system is undermined by soil and water degradation that goes unnoticed and unattended. Under poor governance, incidences of "land grabbing", for example, can easily occur.

3.4.2 Governance of soil and water systems

There are many decisions around soil and water systems that can be a major source of conflict if those affected are not sufficiently consulted in the process of coming to the decisions. Easy examples have to do with conflicts around land and water use – at all levels. If there are no clear rules, or if the rules that exist have not been agreed upon by those using these resources, then conflicts will increase and cooperation between users will decline.

Can you think of how the distribution of decision-making within farm families affects the management of soil and water systems in the farm? Could you imagine this changing?

An example of an area in which this is particularly essential is water management. Water can be the source of considerable conflict – for instance because it is overused upstream at the cost of downstream users; or because more groundwater is consumed than is recharged – on purpose or because no one cares to intervene. Water conflicts can also occur when large storage reservoirs are created – closing down the supply to flood-based farm areas further down. These changes are not necessarily always for the better – serving an economic good or social benefit – but often they are the result of political power play or lack of interest in the affairs of the less well-organised.

Another example is found in "land grabbing", when the government allots land to more profitable landowners, and small-scale farmers living in the area are "forgotten" in the process and get pushed out (see Figure 29).

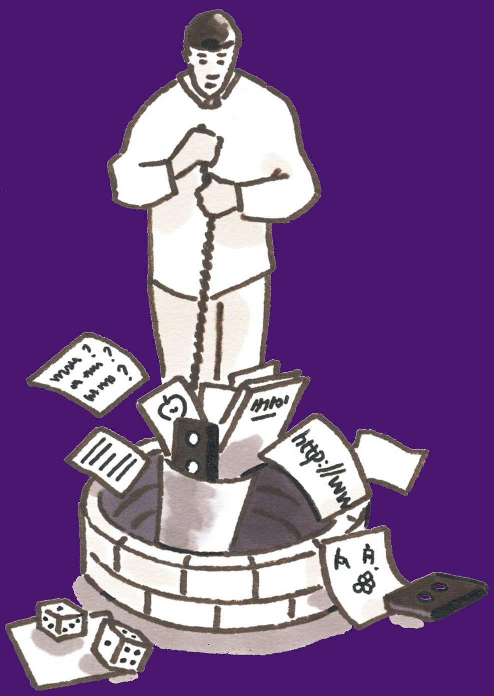
- What are governance issues around water harvesting in a community-led project in India? (Go to Article R2.11)
- Are farmers organised for land and water management in your area? How effective is this? Can it be improved?

Governance plays out at different levels – as shown above at national, local and community level. Governance is also important at the household level. It has to do with decisions on division of tasks, the decision-making on the farm and the distribution of benefits. Some family members may already have very heavy workloads and this may be aggravated or relieved by changes in water supply (e.g. being more or less reliable, closer to the home or further away) – or changes in practices (e.g. new maintenance tasks related to erosion control efforts, more need for weeding, or putting energy into composting or mulching, etc.). Decision-making on investments or changes in practices may rest with some (elder/younger, male/female) but not all of the family members and so may the distribution of cash income or farm surpluses. These changes will affect the way farming develops – positively or negatively.

3.5 Sources for this learning block

- Rogers, P. and Hall, A.W. 2003. **Effective Water Governance**. Global Water Partnership Technical Committee, Sweden.

EDUCATIONAL RESOURCES
for Module 2



How can students reflect more deeply about concepts of soil and water sustainability and small-scale farming? Throughout the three learning blocks, different educational resources have been suggested to help stimulate discussions and as material for assignments. These are brought together in this section, and include games, exercises, articles, photos, videos, farmer interview checklist and field exercises, as well as references for further reading.

R1. Games

In this section, we offer two games to help get students to understand specific aspects of soil and water systems better.

R1.1 Soil Game

Objectives of the game: To get students to understand the importance of all five elements in the soil.
Total time involved: 20-30 minutes
Number of participants needed: at least 10
Materials: Photocopy and cut out cards as per below

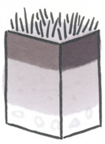
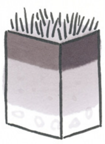
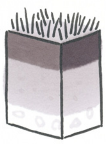
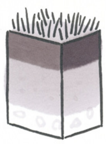
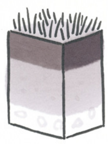
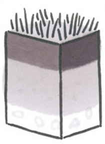
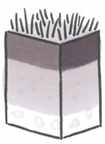
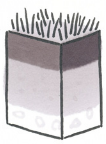
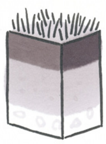
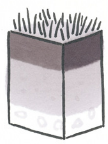
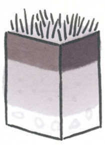
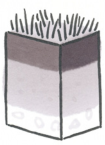
Methodology:

- Divide the students up into five groups.
- Cut the cards from the two sheets. There are fifty cards in total. The cards contain images of (1) organic matter (2) soil biota (3) soil moisture (4) soil minerals (5) air. Shuffle the fifty cards and give each group ten cards at random.
- Now tell the groups that they have 10 minutes to change some of their cards with other groups and that the challenge is to come to a balanced soil in the end.
- Keep an eye on the time and let the groups interact and change cards for 10 minutes. Then let each group display their final selection of cards.
- The best score is to have soil that has all five elements. In principle one could have two cards of each of the five elements. Discuss with students that a healthy soil is a healthy mixture of (1) organic matter (2) soil biota (3) soil moisture (4) soil minerals (5) air. If even one element is missing – the soil will not sustain farming. Explain again what the different components stand for (See sub-section 1.2.1 on pp 10-11).

Discussion:

On the basis of the final selection of the groups: what happens if soils have too much moisture or too much organic material. Or can there never be too much?

				
				
				
	AIR	AIR	AIR	AIR
AIR	AIR	AIR	AIR	AIR

AIR	**AIR**	**AIR**	**AIR**	**AIR**
				
				
				
				

R1.2 Diet-Soil Nutrient Game

Objectives of the game: To help students understand the relative importance of main soil nutrients, by comparing it to something they know well: a typical main meal.
Total time involved: 20-30 minutes during class time
Materials: Paper and markers

Methodology:

- Read Article R2.1 - found in the Appendix to this module.
- This article outlines an example of how to make an analogy between the main nutrients that plants need and a typical diet of Kenya.
- Modify the meal to reflect a typical diet in your region, and follow what the authors did in the article – with your students.

R2. Articles of practical experiences

Objective: To use articles on small-scale farming experiences from around the world to deepen learnings about soil & water sustainability.
Materials: All articles can be retrieved from ILEIA's website (see links by articles), while a selection of articles (indicated by [A]) is included in the Appendix at the end of this section.
Methodology: These cases can be used as additional reading material, as part of classroom discussions, or as part of student assignments. One suggestion is to have students prepare presentations on the basis of the cases and address specific questions as part of this. Some questions are suggested.

Figure 30: Using LEISA articles to stimulate discussion on practical implications

[A] Article R2.1: TALKING SOIL SCIENCE WITH FARMERS (2008)

(Refer to game R1.2)

[A] Article R2.2: BURNING AND SOIL FERTILITY IN NORTHERN GHANA (1999)

Suggested questions:
- Looking at the nutrient cycle above, what do you think happens to nutrients if you burn the biomass?
- How will this affect the nutrient cycle?
- Why is burning a good option if you can shift land every few years?
- What could be a disadvantage to women if burning is stopped?
- Comparing the three methods, how is labour affected?

Article pack R2.3: BUILDING UP SOIL ORGANIC MATTER AND NUTRIENT BUFFERS

Mulching with crop residues

1. Traditional mulching practices in Burkina Faso (1998) (Link to: http://ileia.leisa.info/ index.php?url=article-details.tpl&p[_id]=69392)
2. Looking at quality of residues as soil amendments in Kenya (2006)
3. Improving soil fertility with locally available inputs in the South Pacific (1990) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=69132)

Suggested questions:
- How can mulching would affect the nutrient cycle as well as soil moisture.
- What are different factors that affect how suitable materials are to being used as mulch?
- What is the C:N ratio and how important is it to the availability of Nitrogen?
- What are the different kinds of inputs that could be used in your region?
- What would be different factors in your region that might affect whether farmers choose to mulch their crop residues or not?

Using cover crops and green manures

a. Overview on cover crops and green manures (2003)
b. Improving fertility of salinated soils with green manures in Sri Lanka (2008) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=209099)

Suggested questions:
- What is the difference between cover crops and green manures?
- What are advantages of maintaining a cover on farmers' fields?
- Looking at the example from Sri Lanka, how can green manures help reclaim polluted soils?
- Do you already know of examples of cc/gm in your country?
- Why may farmers not be interested in using green manures just for the sake of increasing soil fertility?
- What could be other uses of cover crops that will get farmers interested in planting them?

Applying manure or compost

Improving soil fertility through vermicomposting in India (2005) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=76747)

Suggested questions:
- What do composts do to help farmers' soil and water systems?
- Why would farmers choose to compost rather than simply placing residues as mulch on their fields?
- Would vermicomposting be relevant in your region? Why or why not?

Applying inorganic fertilizer

Using chemical inputs to kickstart establishment of legumes in degraded zones (2003) (Link to: ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=12706)

Suggested questions:

- What can farmers do if the nutrient pool in the soil is so deficient that they need help to kickstart growth?
- What are advantages and disadvantages of using fertilizers for small-scale farmers?

Trees and agroforestry

a. Fruit trees for ecological restoration and income in China (2003)

b. *See also related article in Article Pack 10 below*

Suggested questions:

- Why is it difficult to get farmers to address soil degradation on its own? What are factors that could motivate farmers to change practices?
- In China, what policies were taken by the government to help encourage erosion control practices?
- Draw a soil nutrient cycle for this case.

Improved fallow

a. Overview article (1987) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=68981)

b. *See also related article in Article Pack 9 below*

Suggested questions:

- What are different types of improved fallowing described in the article?
- What are advantages and disadvantages of improved fallowing, and what would encourage farmers to adopt it?
- What does the World Agroforestry Centre (ICRAF) call improved fallows and how does it work?

Conservation Agriculture

a. Overview of Conservation agriculture (2002)

b. Specific CA case study about maize farmers in Mexico (2008) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=209095)

Suggested questions:

- What are the three principles of CA? How do they affect the soil nutrient and soil moisture cycles?
- When reducing ploughing, growth of weeds increase, so CA farmers initially must use more herbicides. What is the reasoning for herbicide use being less necessary with time? Do you think that is the case in your country?
- What is the difference between Slash & Mulch and Slash & Burn? How do these practices treat the soil differently?
- Can low-cash farmers or land-insecure farmers adopt CA? What conditions would need to be in place for them to adapt to CA practices?
- Is CA possible in your country? Why or why not?

Article pack R2.4: BUILDING UP SOIL MOISTURE - AND EROSION CONTROL - BUFFER

Using in-field water conservation and rainwater retention practices

a. Contour bunds & ridges and cisterns in Egypt and Middle East (2003): http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=12668

b. Comparing terracing practices in upland Uganda, South Africa, India and Indonesia (2003) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=12704)

c. Water harvesting innovations in Kenya (2003)

Suggested questions:

- What are the benefits of farmers carrying out these practices?
- What are different methods used to stabilise the terraces, bunds and ridges?
- What are different methods used by farmers in these articles in order to make the most of low rainwater?
- What do farmers in your region do to counter erosion, and capture runoff water?

Article R2.5: BIOCHAR PRODUCTION AND CLIMATE CHANGE

Short overview on ileia blog (Leisa's Farm, 2009) Link to: http://familyfarming.typepad.com/leisas_farm/2009/09/biochar-gives-new-meaning-to-charcoal.html

Suggested questions:
- How does biochar differ from charcoal production?
- What are the benefits of biochar in terms of the soil, and in terms of the bigger question of mitigating climate change?
- Could this idea work for small-scale farmers in your region?
- What might be some bottlenecks for it to work?

Article R2.6: WOMEN AND ACCES TO LAND

Women and land after conflict in Rwanda (2009) Link to: http://ileia.leisa.info/index.php?url=getblob.php&o_id=236377&a_id=211&a_seq=0

Suggested questions:
- Female-headed households often experience inequalities in access to resources and income-generating opportunities. Conflicts often make women poorer, but following the genocide in Rwanda, how did new opportunities come up for rural women?
- What is the situation for farmer women in your region? How easy is it for them to get access to land? What do you think of this situation?

Article pack R2.7: IRRIGATION SYSTEMS FOR SMALL-SCALE FARMERS

Improving irrigation practices

Learning from a 4 century canal system in Nepal (1997): http://ileia.leisa.info/index.php?url=show-blob-html.tpl&p[o_id]=12193&p[a_id]=211&p[a_seq]=1

Groundwater irrigation practices

Improving irrigation efficiency in Tunisian oasis agriculture (1998):

Suggested questions:
- In Tunisia, rainwater is very low, so two groundwater sources are used to irrigate farmers' fields. What are the two sources, and what are the long-term implications of using them?
- How have farmers' practices changed over the years, and why do the authors call for a return to traditional systems?
- What did the authors discover that meant that a technical solution is not adequate? How could better governance of the system improve its sustainability?

Floodwater irrigation practices

Spate irrigation in (semi-)arid regions of the world (2009):

Suggested questions:

- What is spate irrigation and how do farmers make use of flash floods to optimise soil moisture?
- How does spate irrigation also improve soil fertility?
- If your region is (semi-)arid, could this practice work there?

Article pack R2.8: ECOLOGICAL ASPECTS OF SOIL AND WATER SUSTAINABILITY

Ecological buffering of farms

a. Sustainable farming practices that mitigated impact of Hurricane Mitch (Central America – 2001)

b. Adaptive practices in a flood-prone area in India (2008) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=219108)

Suggested questions:

- What are different practices that farmers use to enhance their ability to prepare for and also withstand disasters such as flooding or destructive storms?
- Why did some farmers in Central America manage to withstand Hurricane Mitch better than others?
- How can policy-makers learn from these stories? What kinds of policies could support farmers adopting sustainable practices?

Watershed management improvement

a. Community-led water harvesting in India (2000): *NB: This article is also part of the discussion on Governance (see Article R.11)*

b. Successful watershed management in Pimpalgaon Wagha, India (1995): http://ileia.leisa.info/index.php?url=show-blob-html.tpl&p[o_id]=12129&p[a_id]=211&p[a_seq]=1

Suggested questions:

- Summarise the processes that led to better water management at a community/ watershed level.
- How were people in whole communities involved in the project, and how did it affect their social situation?
- While these two articles describe watershed management in India, could this type of initiative work in your country?

Article pack R2.9: SOCIO-CULTURAL ASPECTS OF SOIL AND WATER SUSTAINABILITY

Understanding farmer perspectives on sustainability

From soil erosion to soil quality (Honduras - 2003)

Suggested questions:
- While small-scale farmers used more and more steep slopes in Honduras, creating a situation of accelerated erosion, why didn't the farmers recognise erosion as a problem?
- How did the extensionists change their approach to get farmers to adopt more sustainable practices?

Land tenure policies

a. Need for land reform in Brazil and
b. About Brazil's Landless Movement (MST) (Link to: http://ileia.leisa.info/index.php?url=article-details.tpl&p[_id]=12684)
c. Farmers'union fighting for land in indonesia (2008) Link to: http://ileia.leisa.info/index.php?url=getblob.php&o_id=214959&a_id=211&a_seq=0

Suggested questions:
- In Brazil, demand for fair land redistribution has increased steadily in recent decades. In spite of several actions taking place throughout the years, the land issue continues to be a life or death struggle. Why is this?
- What are examples of different approaches to land redistribution? The programme set up by Cardoso had good and bad aspects – what are they?
- In Indonesia, how did farmers hook up with NGOs in order to get closer to gaining access to land?
- What is the situation for small-scale farmers in your country, in terms of land tenure? How difficult is it to get access to land ownership? How could this be improved?

Special land use policies

Improved fallows and policy-making with communities in Zambia (2005)

Suggested questions:
- What kinds of practices went against efforts to establish improved fallowing in Zambia, and what were different by-laws introduced by the government to protect farmers adopting this new practice?
- How did the government in Zambia get communities involved in abiding by new by-laws?
- What kinds of things could communities take care of themselves, and what help did they need by outside government in order to safeguard the by-laws?

Article pack R2.10: ECONOMIC ASPECTS OF SOIL AND WATER SUSTAINABILITY

Economic buffers for farmers

Different interests, common concerns and shared benefits (Vietnam - 2008)

Suggested questions:

- How did this project get farmers on steep slopes to adopt more sustainable soil management practices? What was the final mix of practices chosen?
- This project took care to include farmers – as well as researchers and extensionists - from the start. Why, and how did this affect the sustainability of the results?

Fertilizer subsidies

Fertilizer subsidies as a way out of poverty for farmers in Malawi (2008)

Suggested debate:

- Divide the students into two, to take on the two sides – related to your region.
- What were positive – and negative - effects of a fertilizer subsidy programme in Malawi?
- Argue whether such a programme would be good for farmers in your own country.

Article R2.11: GOVERNANCE ASPECTS OF SOIL AND WATER SUSTAINABILITY

Community-led water harvesting in India: (2000) *(NB: this article is also part of Article pack R.8 discussion)*

Suggested questions:

- What were different approaches that communities took to deal with the water crisis in India?
- Focus on the box at the end of the article, to discuss governance implications of communities leading their own water harvesting efforts.

R3. Photo gallery

Objectives: To use as illustrations for teaching, to stimulate discussions – to help students understand the links between what is going on in the wider context and soil and water systems on the farm

Total time involved: Presentation during class time (20-30 minutes)

Materials: Photo gallery as powerpoint presentation with beamer, or printout (see Appendix at end of Module)

Methodology:

- Present the photographs and ask a number of questions about the photo to help stimulate ideas: for example, what do they observe in the photo, and what does it mean in relation to soil and water systems (reflect on more than simply ecological aspects)
- Use the photographs to discuss similar initiatives in your region.

Photo Nr	Title	Explanation
1	**Sand-blocked water channel in Rajasthan, India**	Rajasthan is the dryest region of India. It is a vast, arid, unfriendly and tough terrain with shifting sand dunes, sparse population, extreme temperatures, stunted vegetation and very little arable land. Faced with deep brackish groundwater, erratic rainfall and recurring droughts, local communities have developed a tradition of seasonal migration and livestock rearing. The region is cross-cut by canals but with the drought the canals have dried up and farmers realised their vulnerability.
2	***Waru waru* (or raised-bed) agriculture is a technology developed over centuries in the Peruvian Andes**	Archaeological excavations of raised fields demonstrated that farmers began constructing them by 1000 BC. *Waru waru* agriculture makes it possible to bring into production the low-lying, flood prone, poorly drained lands found all over the *Altiplano* (mountain plains). When filled with water, the shallow canals ensure a microclimate that acts as a buffer against night frosts and provides moisture during droughts, and drainage during the rainy season. The canals also act as barriers to keep out crawling insect pests. The *waru waru* system provides small-scale farmers with greater harvest security, and reduces the risks associated with frosts and drought.
3	**Small check dams to control erosion in Eritrea**	There are several measures to reduce exposure to erosion. Check dams that can be easily made from local rocks slow down the run-off and serve to accumulate sediment. Often the soil moisture behind the check dams is better too, as can be seen from the adjacent vegetation.
4	**Water availability programme, India**	In Andhra Pradesh as in other areas in India there has been intense development of boreholes of irrigation causing ground water tables to fall in several areas. The Andhra Pradesh Farmer Management Groundwater Systems Project successfully introduced local management of groundwater making sure the gap between water available and consumed was closed. One part of it were discussion in hydrological units on water availability. The different glasses with coloured water show the amount of water in different years highlighting the variability.
5	**Soil in farmers' field still moist and holds together, Eritrea**	Even five months after flooding - the farmer shows how moist his soil still is, due to excellent moisture conservation practices. In this semi-arid climate, soil moisture comes from occasional floods in the summer season (June-August). To preserve moisture, the land is ploughed soon after the flood irrigation and mulched by "planking" (putting boards on the soil) to prevent evaporation.

6	**Very severe erosion resulting from loss of land cover, Ethiopia**	Erosion can damage areas for many years to come, destroying livelihoods and natural buffer capacities in the process. There are several factors that cause erosion - the indiscriminate removal of land cover or unsustainable land-use practices on steep slopes. Interestingly, in several areas, population increase and intensive agriculture have turned the land degradation process around, as land users take a far greater interest in terracing and other land management practices.
7	**Gullying reduces soil moisture, West Bengal, India**	Gullying can play havoc with local soil and water systems. Gullies may be created by uncontrolled sheet flows eroding the soil along its path, which brings the soil moisture to the lowest point. As such, field gullies can dry out soils dramatically.
8	**Ploughing on flood-irrigated land, Eritrea**	There are several ways to conserve the moisture in the soil in semi-arid rainfed farming systems. One is to plough land, in order to move soil moisture to deeper soil layers. Adequate soil moisture in such circumstances ("conservation tillage") makes all the difference in crop production in some areas.
9	**System of Rice Intensification (SRI), India**	In SRI, rice seedlings are transplanted early i.e. within 8 days. The transplanting is done in carefully prepared squares to make weeding easier. In SRI, irrigation is provided intermittently, i.e. every 2-3 days. As a result, the roots of the rice plant develop much more under SRI than under conventional systems.
10	**Terraces in Guangxi, China**	Terraced field for rice cultivation in Guangxi Longji, China. The terraces are reducing runoff and erosion, maintaining soil fertility and making farming operations easier. Terraces here are about 600 to 1200 metres above sea level.
11	**Resource mapping exercise, India**	In many areas land and water management is "nobody's problem" causing things to go out of hand. To reverse this, micro-planning may be effective where land and water resource management is put on collective local agendas. It is often started with a shared understanding of the resource situation at hand. Mapping the resources is a good way to make it visual.
12	**Crops dying from drought in the Karamoja region of Uganda**	Due to climate change, drought is now normal in this area. Farmers here have been forced to keep planting through these conditions. It is becoming more and more difficult to cultivate anything in the region due to this unexpected dry weather.
13	**Composting in India**	This compost was made by layers of biomass and dung in a pit. One pit produces 1 tonne each round, causing productivity increases of 30% more.
14	**Wadi Zabid weir diverting water**	This is an example of a large irrigation system. Built across the river, the weir diverts most of the flow to the command area at this point. Care is required with such structures not to upset the water rights: better control of water at this point in the river may go at the cost of downstream areas.
15	**Small-scale irrigation system in Sindh Pakistan**	Conjunctive use of shallow groundwater pumped into a canal for surface irrigation

R4. Videos

Objectives: To offer visual examples from around the world to complement teachings and to deepen students' understanding of sustainable soil and water practices in small-scale farming, as well as practical initiatives towards sustainability.
Total time involved: Video durations shown below – add time for classroom discussion
Materials: Videos are available on CD-Rom or to be downloaded from Internet (need computer and beamer)
Methodology:
- Present the videos to illustrate points coming up in the lessons, to stimulate discussions.
- Use the videos to discuss related issues and initiatives in your region.

R4.1 Water movement in soil

Link from: http://soils.usda.gov/education/
Duration: 3:10 (suggested for Learning Block 1)
This video explains basic processes of water movement in the soil (produced by United States Department of Agriculture).

R4.2 Soil and water conservation

Link from: http://www.thewaterchannel.tv/index.php?option=com_hwdvideoshare&task=viewvideo&Itemid=53&video_id=243
Duration: 5:20 (suggested for Learning Block 1)
This video shows three methods of soil and water conservation: terracing land, building sand dams and planting trees, applied in Southern Africa (produced by Excellent Development Limited, 2006)

R4.3 Soil and water conservation

Link from: http://www.thewaterchannel.tv/index.php?option=com_hwdvideoshare&task=viewvideo&Itemid=70&video_id=166
Duration: 18:44 (suggested for Learning Block 2)
This video gives a presentation of the soil and water conservation approaches and technologies throughout the world, and the documentation work of WOCAT (World Overview of Conservation Approaches and Technologies) (produced by WOCAT/FAO, 2001)

R5. Farmer visit and field exercises

Figure 31: Visits to farmers bring practical realities alive

Objectives: To get very close to practical realities of small-scale farmers and their soil and water issues; to understand learnings better by seeing a farm and talking to a farmer directly; also to allow students to get practical experience in interviewing and synthesising information.

Time involved: Take time ahead of the interview to prepare interview questions and field exercises. Time for the visit depends on how far farmers live from the school; the interview should last at least 2 hours. Field exercises half a day

Materials: For the interview: pen and paper to take notes, camera and/or video camera; For field exercises, see below.

Methodology:

- Ask farmers about their soil and water practices and how to make them more sustainable (see R5.1 for interview checklist)
- Take the opportunity to also ask students to do some simple soil and water exercises during the visit (see R5.2 for some ideas)
- Following the visit, ask students to make presentations or a written report on their findings.

R5.1 Farmer interview checklist

Ask farmers to describe the soils on their farm and surrounding farms, to categorise the different soils in the area and to describe what makes for a "good soil" and a "bad soil". Listen very carefully and try to understand and replicate how farmers distinguish between soils. This is very important, for students to:

- get an understanding of the local types of soils and the differences between them;
- understand what is important in the experience and local knowledge of farmers: the categories and terms farmers use contain a lot of experience and understanding;
- be able to communicate easily with farmers as you understand the terms they are using.

Reread learning blocks 1 and 2 and make a checklist of soil and water issues for discussion with farmers. Here is a start –

√ What is the soil like? Where do crops grow best?
√ Is the ground sloping a lot?
√ What practices does the farmer use to control erosivity?
√ How is the moisture of the soil at different times in the year?
√ How does it affect plant growth?
√ Do you use special practices to keep the soil moist?
√ How is the climate variability?
√ What is the situation with land security?

Use this checklist for discussion. For deeper understanding you can also ask questions on soil management in the past. Take a fixed point in time – for instance twenty years ago – and ask how soil was managed at that time and compare it with the present.

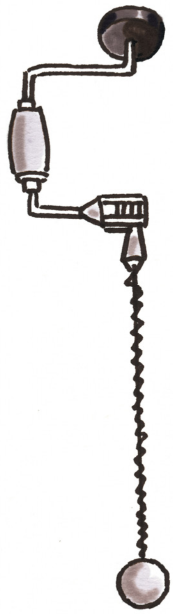


Figure 32: Auger with round knob

R5.2 Investigate soil moisture

There are several easy ways to investigate soil moisture. Here two simple ideas:

- Hold a handful of soil in your hand. Close your hand and then open it again. If the soil sticks together or falls apart in large lumps, there is sufficient soil moisture. If it disintegrates, the soil is too dry.
- Make an auger but have a round knob welded onto the end (see Figure 32). Move this auger into the soil – by turning it around. As long as the soil is moist the auger will move down. But when it becomes difficult to move the auger you have most probably reached the dry layer. In this way you estimate the depth of soil moisture.

R6. Further references for Module 2

This section provides a list of freely accessible resources that can help educators and students dig deeper into issues coming up in this module. Resources include books and guides, as well as websites that offer further resources, photos and videos.

R6.1 Books and guides

Soil and Water Conservation – With a focus on Water Harvesting and Soil Moisture Retention

(A study guide for Farmer Field Schools and Community-based Study Groups)

compiled by Deborah Duveskog, FARMESA/FAO

Available at Ministry of Agriculture and Rural Development, Kenya, Directors office, Kilimose.Cathedral Rd. P.O Box 30028, Nairobi, Kenya

Downloadable as PDF from: ftp://ftp.fao.org/agl/agll/farmspi/FARMESA_SWC1.pdf

Climatic conditions of the semi-arid regions put high demands on farm water management. This study guide is filled with information, exercises and experiments on water harvesting and soil moisture retention. Based on experiences from FARMESA (Farm Level Applied Research Methods for Eastern and Southern Africa) the study guide is intended to assist farmer groups in learning and experimenting on improved soil and water management. Included is also information on how to set up and run a farmers field school.

Water harvesting and soil moisture retention

By Anschuetz J et al. 1997. Agrodok Series 13, 92p.

Available from: Agromisa, PO Box 41, 6700 AA Wageningen, The Netherlands.
Downloadable as PDF from: www.agromisa.org/agrodoks/Agromisa-AD-13-E.pdf

This practical booklet, part of the Agrodok series, describes how rainfall and runoff water can be used to greater effect in agriculture. Many techniques are described briefly and clearly. The water-harvesting techniques covered in this booklet are particularly relevant for arid and semi-arid areas and the section on soil moisture retention contains information valuable for sub-humid regions. (IHG)

Ideas for groundwater management

By Chevalking, S., L. Knoop and F. van Steenbergen. ISBN:978-90-79658-01-52008. Wageningen, The Netherlands: MetaMeta and IUCN

Downloadable as PDF from: www.metameta.nl/downloads/ideas_for_groundwater_management.pdf

Groundwater is best described as the world's real hidden treasure. Almost everything it has, made a difference in providing safe drinking water and livelihood security in times of drought. Major agricultural economies in arid and semi-arid regions are sustained by groundwater use. The aim of this book is to provide ideas on different aspects of groundwater management. This ranges from areas where there is an abundance of subsurface water to areas where the resource is scarce.

InnoWat: Water, innovations, learning and rural livelihoods

By Cleveringa, R., Kay, M. & Cohen, A. (Eds.) (2009), IFAD, International Fund for Agricultural Development, Via Paolo di Dono 44, 00142, Rome, Italy

Downloadable as PDf from: www.ifad.org/english/water/innowat/index.htm

The InnoWat kit is providing tools for project development, implementation and pro-poor waterrelated interventions. The kit includes **synthesis of strategic approaches and additional** fact sheets, topic sheets, tools sheets and case studies. The strategic papers are mostly focusing on the work sphere of IFAD but some of the information in the kit can also be of interest for others.

Gender and water. Securing water for improved rural livelihoods: the multiple-uses systems approach

By Robina Wahaj and Maria Hartl, 2007.

International Fund for Agricultural Development (IFAD), Rome, Italy.
Downloadable as PDF from: www.ifad.org/gender/thematic/water/gender_water.pdf

Securing water is critical to achieving food sovereignty and improving livelihoods. Women manage water resources for domestic and productive uses, and they are getting more attention in the planning of water projects. Multi-purpose water systems address women's concerns better than single-use projects. But further gender-sensitive planning and monitoring is necessary throughout the whole project cycle, as is participation of women in decision-making.

The preparation and use of compost

By Madeleine Inckel,Peter de Smet, Tim Tersmette and Tom Veldkamp, 2005. 65 pp. ISBN 90-8573-006-6. Agrodok no 8. Agromisa, P.O. Box 41, 6700 AA Wageningen, the Netherlands.

Downloadable as PDF from: www.agromisa.org/agrodoks/Agromisa-AD-8-E.pdf

This small manual gives a clear overview of the processes taking place in the soil during composting, and makes practical suggestions on different composting methods, useful for both the tropics and subtropics. Suggestions include different approaches and theories to experiment with: different types of heaps, liquid teas and fermentation methods. It is a practical guide, useful for farmers, students, educators and agricultural field workers. This revised edition is also available in French, Portuguese and Spanish.

Conservation agriculture in Africa series

By Bernard Triomphe, JosefKienzle, Martin Bwalya, Soren Damgaard-Larsen (eds.), 2007. Produced by AfricanConservation Tillage Network / Centre de Coopération Internationale de Recherche Agronomique pour le Développement / Food and Agriculture Organization of the United Nations. Published by ACT : P.O. Box 14733, Westlands, Nairobi 00800, Kenya.

Downloadable as PDF files from:www.worldagroforestry.org/sites/relma/relmapublications

This jointly facilitated series documents the current situation and lessons learned on conservation agriculture (CA) in Africa. It includes eight case studies with examples from Ghana, Zambia, Uganda, Kenya and Tanzania. The booklets provide insights and critical reflection on not only the benefits of CA but also the challenges confronting farmers, such as difficulties in keeping the soil covered, gaining access to equipment and weed control; as well as the challenges faced by institutions in implementing participatory approaches to CA technology.

R6.2 Interesting websites

Conservation and Sustainable Management of Below Ground Biodiversity

http://www.bgbd.net

The Conservation and Sustainable Management of Below Ground Biodiversity is a project co-ordinated by the Tropical Soil Biology and Fertility Institute and supported by the Global Environment Facility and the UN Environment Programme. Its goal is to generate information and knowledge to better manage and conserve below-ground biodiversity in tropical agricultural landscapes.

Food and Agriculture Organisation (FAO)

http://www.fao.org

Gender and Water Alliance

http://www.genderandwater.org/

Established during the second World Water Forum (WWF) in March 2000, this is a global network set up to promote equitable access to and management of safe and adequate water. Its programme and activities include recording and sharing of knowledge and information on gender mainstreaming policies, and reinforcing the profile of gender equity issues at international water related conferences. Their website includes many documents and resources, all of them grouped according to the different "water sectors": agriculture and food, drinking water, environment, sanitation, and integrated water resource management.

Global Soil Map

http://www.globalsoilmap.net/

This is the website that aims to create a new digital world soil map. The site contains country soil maps from a large number of countries.

Groundwater Management

www.groundwatermanagement.org

Training kits, exercises and reference materials concerning participatory groundwater management are part of this site on groundwater management. Intended to bring together scattered experience on groundwater management and its aspects, the site managers welcome collaboration as well as relevant material.

Holistic Agriculture Library

http://www.soilandhealth.org/01aglibrary/01aglibwelcome.html

This internet-based library provides access to many important documents on soils and sustainable practices. It includes interesting historical books that are no longer published, such as old texts from the early 1900s as well as more recent classics.

International Commission on Irrigation and Drainage

http://www.icid.org/

The International Commission on Irrigation and Drainage (ICID) is a NGO based in New Delhi, India. The mission of ICID is to stimulate and promote the development of agriculture in managing water and land resources for irrigation, drainage, flood management and river training applications, including research and development and capacity building for achieving sustainable irrigated agriculture.

International Development Research Centre (IDRC)

www.idrc.ca

IDRC is a Canadian Crown corporation that works in close collaboration with researchers from the developing world in their search for the means to build healthier, more equitable, and more prosperous societies. Concerning groundwater and water supply IDRC has focused on water supply technologies, such as improved water pumps and rooftop water collection systems. Now, the focus lies on water treatment and quality control, water demand management and the devolution of water management to lower levels of government, local organizations and communities. The development of simple water testing kits, which can be used by local people to examine the quality of water, is one example.

Laboratoire d'étude des Interactions Sol - Agrosystème - Hydrosytème

http://www.umr-lisah.fr/

Research facility to look into the interaction between soil, water systems and farming systems. Contains references to papers with a focus on North Africa.

Practical Action

http://www.practicalaction.org

Practical Action believes that simple technologies can be used to challenge poverty.

As part of this programme, the organisation works with people to help them adapt to the effects of climate change. Projects supported in this programme include rainwater harvesting in Zimbabwe, the use of "crescent terraces" in Sudan, and the development of technologies in Bangladesh for growing food on flooded land. The website includes a lot of information about the more than 100 projects implemented by this NGO, as well as a section on "Practical Answers" where you can download technical briefs on adaptation to climate change, and send in technical questions.

Soil maps of Africa

http://eusoils.jrc.ec.europa.eu/esdb_archive/EuDASM/africa/index.htm

This site is a digital archive of a large number of scanned detailed soil maps of Africa – categorised per country.

The Water Channel:

www.thewaterchannel.tv

This website is dedicated to web-based videos on all sorts of water issues relevant to educators on sustainable management. It caters to a broad-based audience, making a large amount of video material available.

Tropical Soil Biology and Fertility Institute

http://www.ciat.cgiar.org/tsbf_institute/

TSBF Institute of CIAT (TSBF-CIAT)

WCA InfoNET

http://www.wca-infonet.org

The WCA infoNET information system is a growing database of information on water conservation and use in agriculture. It was launched to the public in August 2001 and is managed by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID), hosted by FAO. This site includes documents, data, computer programs, discussion groups and links to other relevant websites.

World Association of Soil and Water Conservation (WASWC)

http://www.waswc.org

This organisation provides an interesting forum on sustainable soil and water management practices and policies around the world. It does this through a newsletter and a number of other publications. The newsletter (available in English, Spanish, French, Chinese, Portuguese, Bahasa, Russian, Vietnamese, Arabic and Thai) includes a diverse range of subjects, reporting on important SWC workshops and conferences, policy discussions and highlighting relevant research findings from around the world.

World Overview of Conservation Approaches and Technology

http://www.wocat.net/

WOCAT is dedicated to supporting and documenting sustainable land management practices. It has an extensive data base of local practices – that are available through a range of publications and training programmes

World Soil Information, ISRIC

www.isric.nl

World Soil Information is an independent foundation with a global mandate, involved in a wide range of national and international projects. Among its objectives, ISRIC aims to inform and educate (for example, through the World Soil Museum). It maintains the World Data Centre for Soils since 1989, serving the scientific community. ISRIC also undertakes applied research on land and water resources. ISRIC has built up a collection of more than 20,000 articles, country reports, books and maps with emphasis on developing countries.

World Water Council

http://www.worldwatercouncil.org/

The World Water Council is an international water policy think tank, dedicated to contribute to improved management of the world's water resources. The mission of the World Water Council is to promote awareness and build political commitment on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient conservation, protection, development, planning, management and use of water in all its dimensions on an environmentally sustainable basis for the benefit of all life on earth.

Worldwide Portal to Information on Soil Health

http://mulch.mannlib.cornell.edu

This portal is presented as an international clearing-house and search engine for internet resources on soil covers, organic inputs and soil management. Put together and managed between the Tropical Soil Cover and Organic Resource Exchange Consortium, Cornell University's Mann Agricultural Library and the Agricultural Network Information Center, it offers an extensive database of annotated English and Spanish language resources (documents, events, links to organisations, networks, journals and publications). Also available through the portal are the archives of many different electronic discussions, as well as a series of on-line learning modules.

APPENDIX
for Module 2

This section includes a selection of Articles (referred to in section R2 of Educational Resources) and the printed version of the Photo Gallery (referred to in section R3).

R2. Articles

LEARNING BLOCK 1

Article R2.1: Talking soil science with farmers

Article R2.2: Burning and soil fertility in Northern Ghana

Article pack R2.3: Building up soil organic matter and nutrient buffers (four articles)

Article pack R2.4: Building up soil moisture - and erosion control - buffer (one article)

LEARNING BLOCK 2

Article pack R2.7: Irrigation systems for small-scale farmers (two articles)

LEARNING BLOCK 3

Article pack R2.8: Ecological aspects of soil and water sustainability (two articles)

Article pack R2.9: Socio-cultural aspects of soil and water sustainability (two articles)

Article pack R2.10: Economic aspects of soil and water sustainability (two articles)

Article R2.11: Governance aspects of soil and water sustainability

R3. Photo gallery

Fifteen photos from around the world.

Talking soil science with farmers

R2.1

When agricultural researchers visit farms in order to gather information for their research programmes, farmers rarely get proper feedback. Research information on scientific concepts such as soil fertility and nutrient balances is often considered too abstract for them. Researchers in Kenya returned to farmers to discuss their results in the context of Farmer Field Schools. Through the workshops that ensued, they managed to find a common language to bridge the communication gap.

Pablo Tittonell, Michael Misiko and Isaac Ekise

We researchers often visit farms to extract information, take measurements and samples, and then we leave. We publish our results for the scientific community, assuming that the result of our research will benefit farmers in the long run. However, farmers usually do not get direct feedback about research findings. We also needed better understanding of how they make decisions. When conducting research on soil nutrients in the field in western Kenya, we noticed that farmers very much appreciate feedback. We therefore set out to discuss basic processes together to help them to make decisions on the adoption and use of technology, while also helping us to learn about how farmers make decisions.

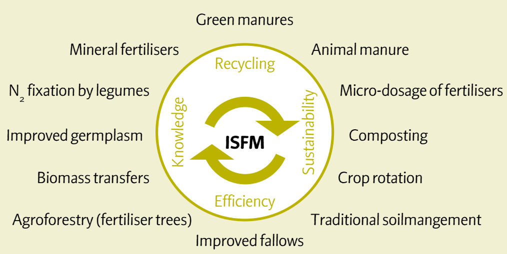
Our research context

Research was conducted on sixty farms in Emuhaya, western Kenya, and concentrated on understanding soil nutrient balances better to help improve integrated soil fertility management (ISFM) strategies (see Box). Soil on smallholder farms of sub-Saharan Africa tends to vary greatly in quality depending on location. Particularly in highly populated areas such as western Kenya, soil fertility typically decreases within a farm the further you move away from the homestead. These heterogeneous patterns, known as soil fertility gradients, result partly from the variability in soil types in the landscape, but also as a consequence of farmers' decisions on applying nutrient resources (e.g. animal manure) as well as where to best use their labour. When either nutrient resources or labour is scarce, farmers tend to concentrate these resources in the fields and gardens around their homesteads. Over time, this pattern of resource allocation leads to the typical picture observed across different areas of sub-Saharan Africa: well growing crops around the homestead or in the village fields versus sparse stands of poorly yielding crops in the bush fields. Clearly, soil fertility gradients need to be taken into consideration when designing ISFM strategies.

Figure 1: A farmers' resource flow map, showing movement of all nutrient resources throughout the farm.

What is integrated soil fertility management?

ISFM is a knowledge-intensive rather than input-intensive approach that aims at raising productivity levels while maintaining the natural resource base. It aims to replenish soil nutrient pools, maximise on-farm recycling of nutrients, reduce nutrient losses to the environment and improve the efficiency of external inputs. ISFM makes use of both local, traditional and scientific knowledge and integrates them into technologies that enable sustainable natural resource management systems. The diagram shows a number of examples of such technologies.



Our data collection included drawing resource flow maps (see example in Figure 1) and calculating nutrient balances, combined with soil sampling from the different field types within farms for laboratory analysis. We also measured the yield of maize crops growing on different fields within the farms, and large differences were observed. We saw that farmers tended to concentrate their organic resources in the home gardens. Very often, crop residues are also collected from the fields and brought to a compost pit where they are mixed with animal manure to be applied to the home gardens in the next season. Farmers used little mineral fertilizer in general, and those who did, applied less than 20 kg/ha (strikingly low when compared with the 200 kg/ha that is common in European agriculture!).

The partial nutrient balances (inputs as mineral and organic fertilizers minus outputs in crop harvest and residues removed) were negative for most fields for all farmers. The outer fields receive few inputs, but they also yield little, so not much is harvested from them. Therefore, the most negative balances were calculated for the close and middle fields, which are where the largest crop harvests are normally obtained. Along a soil fertility gradient, maize yields varied from almost 4 tonnes per hectare near the homestead to less than 0.5 tonnes per hectare in the remote fields.

Making research feedback more accessible

The farmers were keen to obtain the results of our analysis, but handing out reports with tables full of analytical data would not have made sense to them. Therefore, we decided to first discuss with the community some basic concepts on nutrient balances, soil nutrient availability and plant nutrition. We held a workshop with 15 farmers (men and women) at the Emanyonyi Farmer Field School in Emuhaya. First we drew a farm transect on a flip chart, depicting a typical farm there. Farmers recognised the existence of soil fertility gradients and had local names for the different fields within their farms, distinguishing between home gardens, close and mid distance fields, remote fields, valley bottom lands and the grazing sites within the compound. During earlier visits to the farms, farmers had classified their fields according to their perceived fertility, by using the signs +, -, or +/- on the map to indicate fields of good, poor or medium soil fertility (see Figure 2). We next recalled all our research activities on their farms, also handing out the results of the soil analyses. And we provided reference values for the different soil indicators (soil organic carbon, total nitrogen, soil pH, etc.) corresponding to poor and fertile soils in the region.

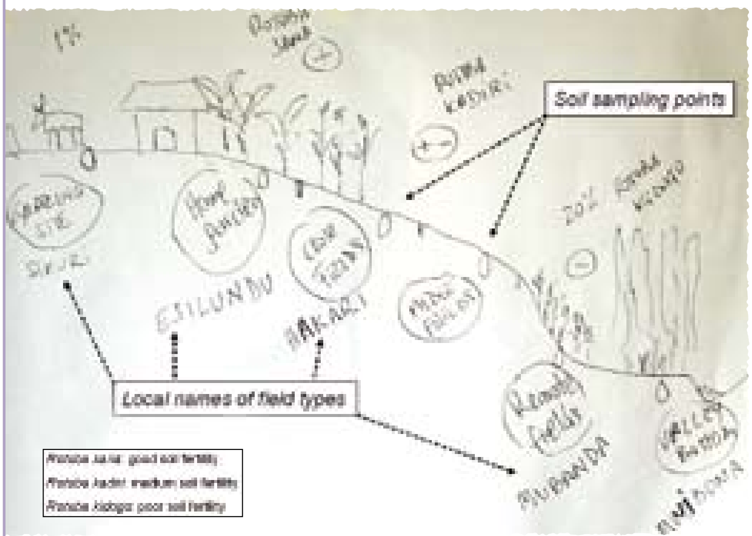


Figure 2: An example of a typical farm transect, drawn with farmers in Emuhaya.

Useful analogies

To make the discussion on plant nutrients and soil fertility indicators more accessible to the farmers, we used a simple analogy focusing on the typical meal consumed in the area. A typical meal includes a relatively large portion of *ugali* (a warm porridge made out of white maize flour), a smaller portion of *nyama* (normally stewed or fried chopped beef) and an even smaller portion of *sukuma wikii* (boiled kale, cabbage or other local vegetables). We compared crops with the human body, which needs food to grow and function. We explained that the food of crops comprises mainly N, P, K and other nutrients in smaller proportions. We used local terms for the elements, and likened N to *ugali*, P to *nyama*, and K to *sukuma wikii*. A well growing, healthy crop needs a larger amount of *ugali* (N), a smaller amount of *nyama* (P), and some *sukuma* (K). (The latter is an assumption that works fairly well for the situation of Emuhaya, where K deficiencies are not generalised and only in few cases were crop responses to K fertilizers observed.) We also explained that next to N, P and K, plants need other macro- and micro- nutrients, which are to the crop like the soup, the sauces, the salt and the spices that we consume together with our meal.

Looking at the reports, some of the participants asked about the roles of soil carbon and pH, following the proposed analogy. We indicated that soil C represents the 'plate' where the food is served; the amount of food can be plenty, enough for a good crop, but if the plate is too small only a small amount of food can be served (little availability). Soil pH was compared to the taste of the food, too low pH values indicating a bad taste; again, food can be available, but if it does not taste good the crop will not take it up completely.

With these analogies, we took two examples from the results of the soil analysis for illustration, using reference values for the local soils provided to farmers, together with the analytical results. One of the examples was a soil sample with a relatively high K content, and low C, N and P contents (drawn as a big plate with plenty of *sukuma* and little *nyama* and *ugali*). The other example had low C and N, K was almost adequate, and P was in excess (the plate was not big enough to contain all the *nyama*). Next to the drawing of a plate with *ugali*, *nyama* and *sukuma*, coloured bar charts were used to represent these soil indicators. After repeatedly drawing the bar charts next to the "meals" farmers got familiar with such graphic representation, so that only bar charts were necessary for illustrations later on. However, we kept the analogy going as farmers often got a good laugh out of certain images used, like the one about a person who is fed exclusively *ugali* who becomes fat but totally unproductive!

Understanding nutrient resources

Our next objective was to characterise the various nutrient resources available to farmers, on the basis of their nutrient content. When requested to recall the different nutrient resources known to them, farmers mentioned mineral fertilizers first, then farmyard manure and finally legumes and green manures. Some of the farmers pointed out that the main problem with farmyard manure was the small quantity available on the farm, which could fertilize only a small portion of their land. Where livestock is not kept in a stall, the effort needed to compost, carry and apply manure was also mentioned as a constraint to the use of manure as fertilizer. Few farmers, by the way, seemed to be aware of the fact that the quality of their manure is influenced by their animals' diet, a point that raised many questions in the group.

One farmer asked why she got greater yields in certain fields than in others, even if she had applied the same type and amount of fertilizer throughout her farm. She said she used the same maize variety in all her fields, planted and weeded the fields at the same time, and used the same planting density; however, she had not noticed differences in the visual properties of the soils within her farm, such as texture, slope or soil depth. The other farmers came up with possible causes of yield differences across the farm, such as varying pest or disease pressures on different fields, or differences in the placement of the fertilizer (e.g. by two different workers). Subsequently, we used the report of the soil analysis from her farm and drew a simple sketch to illustrate the variability she observed, using once again the analogy described above. Pointing to this sketch we suggested that she had probably applied more nutrient resources in the past to the fields around her homestead. This she confirmed. It turned out to be a very useful example as the results of the soil analysis clearly indicated higher N, P and K contents in her close fields. More

Photo: Pablo Tittonell

Reseacher and famer exchanging different perspectives and knowledge about soils.

nutrients present in the soil, together with those added by the fertilizer, led to higher yields near the homestead.

Explaining nutrient balances

Discussing the concept of nutrient balances proved to be more difficult. We started by comparing it to cash balances that are necessary to run a shop: “If we want a profit, our balances should be positive, which means that the earnings should be more than the expenditures”. We explained that in the various fields of a farm, it is however practically impossible to have positive nutrient balances, but at least they should not be too negative. If nutrient balances are negative for long periods of time, the soils will be depleted. Flows of nutrients in harvested crops from the outer fields to the homestead and outflows to the market were listed. Farmers were surprised about the idea that nutrients are brought into the farm system when livestock grazing in communal land is kept on the farm at night. This discussion ended with a general feeling that the concept of nutrient balances appeared to be too abstract and puzzling to farmers: “So, the nutrient balances are *most negative* in the fields where we get the *best yields*?!!...”

Bridging farmer and scientific knowledge

Unlike technologies depending purely on inputs, the Integrated Soil Fertility Management approach is knowledge-intensive. To a large extent, ISFM strategies can be built on what farmers know and on their logic. Farmers’ knowledge is largely constructed from past experience, and their adaptive capacity allows them to manage extremely complex systems (in places like western Kenya, farmers have managed to sustain their families on less than 1 hectare). Nevertheless, principles such as “nutrient stocks”, “nutrient losses” or the “efficiency of nutrient capture”, which are central to ISFM, are often too abstract. The mere concept of “nutrients” is unfamiliar to many farmers. Nevertheless, our discussions with farmers revealed that they appreciate to have direct contact with scientists, to be able to access the results of their research, and to discuss issues as complex as nutrient cycling. They showed interest in learning more about the underlying processes affecting soil fertility and particularly on how their decisions contribute to soil heterogeneity.

This experience suggests that ISFM strategies will not sink down in rural communities unless parallel strategies are in place to empower farmers to make their own choices and decisions in relation to technology use and adoption. Specifically on the problem of poor soil fertility, the strategies for disseminating ISFM should go beyond comparing technologies from demonstration plots. They should place emphasis on discussing basic processes governing soil fertility together with farmers.

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Assessment of non-burning and organic-manuring practices

0.I. Aalangdong, J.M. Kombiok & A.Z. Salifu

photo: Bert Lof

Farmers, researchers and extension agents in northern Ghana regard low soil fertility as a major constraint to crop production. Increasing human population has led to the shortening of bush fallowing, a traditional method to replenish soil nutrients. Application of inorganic fertiliser to restore fertility has become non-profitable, as prices are beyond the reach of smallholders. They are therefore being encouraged to intensify their farming through intercropping, crop rotation, agroforestry, soil and water conservation, and organic manuring. Traditionally, widespread dry-season burning of vegetation was practised. Burning as a labour-saving tool to clear land and prevent weed infestation is now being brought into question, because more organic matter is needed in the soil. Many development agencies now advocate non-burning.

Assessment methods

Case studies of non-burning at Goziire (Upper West Region) and of non-burning and organic manuring at Zagsilaari (Northern Region) had suggested that these practices support sustainable agriculture by improving soil fertility and conserving soil and water (Kombiok, et al 1997). Existing experiences in sustainable agriculture can serve as examples for other communities in the same agro-ecological zone. However, other farmers are more likely to be convinced and to try these practices if they had more information on inputs and yields. A follow-up study was therefore designed to quantify the inputs and outputs of non-burning and organic-manuring practices, and to assess the benefits of these practices from the farmers' point of view.

The follow-up study was conducted in the 1998 cropping season (June-November) at the case-study sites chosen with extension agents from MOFA and some NGOs. At each site, four farmers - two who practise non-burning and/or organic manuring, and two who do not but were interested in the study - were selected.

In each farm, four 10x10m plots of various crops were demarcated randomly. Data were collected on labour inputs, plant height and population, and crop yields. During farmers' fora at the end of the cropping season, the communities assessed the advantages, disadvantages and problems associated with the practices. Participatory Rural Appraisal techniques were used to encourage them to discuss the issues and socioeconomic implications freely and to give their opinions.

Increased grain yields

At Goziire, sorghum was taller after three-year fallow than in the non-burnt plots. Millet in the non-burnt plots with farmyard manure was twice as tall as in the burnt plots with manure or without. Sorghum yields ranged from 1.1 to 1.4 t/ha and were higher after non-burnt fallow than after non-burnt continuous cropping, even with FYM. Yields of millet were lower (1.1-1.2 t/ha) than those of sorghum with the same treatment, and were as low as 0.48 t/ha even with FYM in the regularly burnt area.

At Zagsilaari, maize yields in the non-burnt plots were more than double those in the burnt plots. Sorghum ▶

Table 1: Grain yields (kg) from 10x10m areas on burnt and non-burnt plots at Zagsilaari

Farmer	Practice	Crop	Plot 1	Plot 2	Plot 3	Plot 4	Mean
David Agongo	Non-burning	Maize	27.0	23.0	26.0	24.0	25.0
Iddi Dorkurugu	Non-burning	Maize	11.0	10.0	8.0	11.0	10.0
Yakubu Mbangba	Burning	Maize	10.0	9.0	6.0	7.0	8.0
Alitu Dorkurugu	Burning	Maize	8.0	8.0	9.0	9.0	8.5
David Agongo	Non-burning	Sorghum	3.0	3.0	2.5	3.0	2.9
Yakubu Mbangba	Burning	Sorghum	2.0	1.0	1.5	1.5	1.5

yields in non-burnt plots were double those in the burnt plots (Table 1) and the sorghum heads were longer (45 vs. 34cm) and heavier (1650 vs. 1500 g).

The number of years an area is not burnt also affects crop yields. At Zagsilaari, plots not burnt for six years had higher yields than those not burnt for three years. This may be due to the longer accumulation of organic matter and the greater amount of soil nutrients for crop uptake.

More labour for weeding

Data on labour for land preparation, planting, weeding and applying manure/fertiliser were collected at Zagsilaari. All the farmers used bullock ploughs to prepare their land, but only David Agongo owns a pair of bullocks and a plough. The others hired bullock services, paying twenty thousand cedis per acre. Labour inputs for land preparation did not differ between practices, but more labour was needed to weed the non-burnt plots than those that had been burnt regularly (Table 2).

Farmers' fora

The farmers' fora were open to both men and women, but only about 20% of the participants were women. At both sites, the farmers agreed that non-burning and organic manuring bring tremendous benefits.

Table 2: Estimated labour inputs (person-days) in burnt and non-burnt plots cultivated to maize and sorghum in Zagsilaari

Farmer	Crop	Practice	Ploughing	Planting	Weeding	Applying manure/fertiliser
David Agongo	Maize	Non-burning	2	4	13	-
Dorkurugu	Maize	Non-burning	2.5	11	21	6
Yakubu Mbangba	Maize	Burning	3	6	11	-
Alitu Dorkurugu	Maize	Burning	2	3	8	8
David Agongo	Sorghum	Non-burning	2	3	14	-
Yakubu Mbangba	Sorghum	Burning	4	6.5	11	-

Communities develop strategic burning

In recent years, the awareness-raising campaigns about non-burning have led to heated discussions in communities in northern Ghana. Burning of grass on fallow and bushland has several advantages: it removes heavy vegetation and reduces labour inputs to bring fallowed land back into cultivation, it reduces the incidence of weeds and pests in cropland, it prevents bush encroachment on grazing areas, it gets rid of low-quality over-mature grass and makes way for fresh regrowth of grass nutritious for livestock, it stimulates the germination of certain tree species, and it reduces the risk of devastating uncontrolled flash fires that can destroy crops and homes. On the other hand, farmers are aware that burning also destroys vegetative biomass that could be used to improve soil quality.

Through their observations and discussions, some communities are now developing a more differentiated view of fire: it is a question not of burning or non-burning but rather of when, where and how burning is practised. Burning at the right time of year, under strict control, can achieve the positive effects and reduce the negative impact of this practice. These communities have drawn up by-laws that stipulate when and where burning is allowed, and have strict social controls to ensure that burning outside these limits is punished. There is still room for action research by communities to determine the best ways to employ burning as a valuable tool when used strategically and with caution.

Source: Discussion during ILEIA research workshop, March 1999.

Advantages of non-burning at Goziire mentioned by the farmers were:

- regrowth of natural vegetation, especially grasses and trees for grazing and construction
- better establishment of wood lot plantations and improved yields of shea and *dawadawa (Parkia biglobosa)* trees
- good conservation of soil and water, thus reducing erosion, improving crop germination and increasing crop yields
- retention of livestock in village because forage is available during the dry season.

Benefits of non-burning and organic manuring mentioned by Zagsilaari farmers were:

- improvement of soil fertility
- reduction in soil erosion
- increased crop yields and self-sufficiency in food for families
- use of less land, allowing sedentary agriculture.

Disadvantages in non-burning were:

- fewer dead trees for woman to collect as firewood
- inaccessibility, with limited mobility and visibility; bushes become hideouts for thieves
- proliferation of pests such as rodents and insects which destroy crops.

Successful fire control

Conservation of natural vegetation and the protection of other plant material can provide the organic matter needed to enhance soil fertility. This can be achieved by reducing the frequency and extent of burning.

The success story of Goziire in this respect was a result of awareness creation that led the local people to mobilise themselves into a volunteer group to control fire. The community instituted locally endorsed by-laws. Culprits are sanctioned and must pay fines. The community also has the support of the Paramount Chief of Nandom to enforce the by-laws. The heightened awareness spread to surrounding villages, which have now also adopted non-burning.

More action needed

Farmers are seeking improved crop yields with low levels of external inputs. The study has shown that yields are higher where non-burning and organic manuring are practised. The sustainability of soil fertility depends on the availability of organic matter and this is possible only if crop residues and bush vegetation, the major sources of organic matter, are not burnt. We therefore recommend that:

- More education be given by environmental NG0s, government organisations, MOFA and District Assemblies to enhance awareness of the implications of bush burning.
- Traditional rulers, in consultation with their communities, institute bush fire bye-laws endorsed by the District Assemblies.
- Non-burning and organic-manuring practices be incorporated into school curricula.
- Fire-fighting volunteers be trained and supported by the Ghana National Fire Service and the District Assemblies.
- Communities be organised into groups to facilitate the training and adoption of non-burning and organic manuring.
- Workshops, seminars, video shows, and field visits be part of the educational programmes
- Farmers be encouraged to adopt technologies such as oversowing, cover cropping, improved fallow and agroforestry as complementary measures to increase organic matter.

Long-term monitoring of non-burning and organic-manuring practices would allow the quantification of their short- and long-term impact on agricultural production and environmental quality. Comparisons should be made on the basis of simple economic analyses.

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Managing organic resources for soil amendment

Ken Giller, Michael Misiko and Pablo Tittonell

Soil fertility management is a key issue for sustaining agricultural production in the tropics. Organic resources are important for short-term nutrient availability, as well as for longer-term maintenance of soil organic matter. For smallholder farmers, organic materials are an important source of nutrients, and necessary to manage soil fertility. However, the amount of organic material available on-farm is often limited in supply, and differs widely in quality. This is why the little that is available needs to be used as efficiently as possible.

Photo: Michael Misiko

Lucy Aojata, a local farmer in Chakol, western Kenya, explains local understanding of quality of organic resources before farmers and researchers started a joint experiment.

Did you ever wonder why some leaves of plants just seem to vanish as soon as they fall to the ground? Or why you can still find remains of maize stalks a year after they were turned into the soil? There are many different types of organic matter and to use these effectively as soil amendments it is important to understand how to manage them for nutrient supply or soil cover. The "quality" of organic resources determines their effectiveness for different uses; quality indicators are the carbon-to-nitrogen ratio, the lignin and tannin (polyphenol) contents. Through working together with smallholder farmers in Africa some tools have been developed that can be used in joint-learning research. Here we describe our experiences and important lessons learned.

Creating decision trees

The importance of the "quality" of plant residues in governing rates of decomposition and effects on soil fertility has long been recognised. A decision tree was developed to guide the use of organic resources based on our understanding of the critical concentrations of nitrogen, lignin and tannins (see Figure 1). This simple diagram summarises knowledge of the relationships between the chemical quality of plant leaves and litter and their rates of decomposition and nitrogen release. Scientists may feel the need for a laboratory to analyse the quality of the residues, but simple characteristics can be used instead of some chemical tests. Nitrogen concentrations of leaves and litters can be estimated simply on the basis of their colour. If a leaf can be crushed to a powder when dry this indicates it contains little lignin as leaves rich in lignin are stiffer and more fibrous. Farmers in Zimbabwe, when asked which multi-purpose legume tree species they would value as a fodder for their cattle, simply tasted them and readily identified those rich in reactive polyphenols. This "tongue test" is due to the bitter, astringent taste caused by the polyphenols binding with salivary proteins, and clearly separates out species with strong protein-binding capacity.

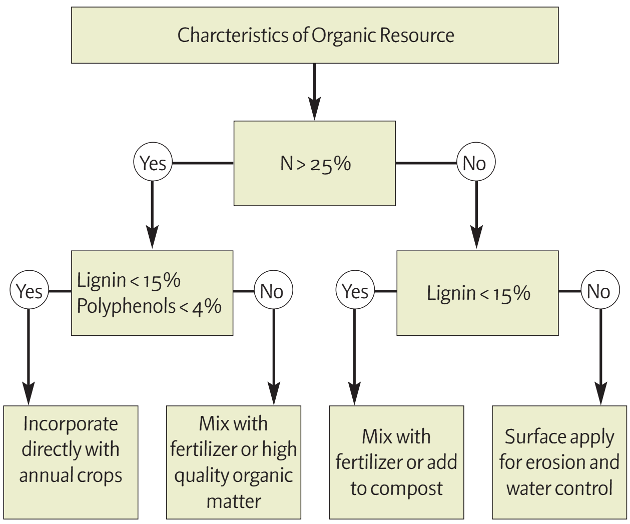

Figure 1. A decision tree to assist management of organic resources in agriculture (from Palm et al., 2001).

Such simple field tests made it possible to create a decision tree that can be used as a tool to discuss litter/fodder quality directly with farmers in participatory research. This tool can also be explained in pictures (Figure 2). Farmer field schools in western Kenya have been experimenting with different qualities of organic residues for soil amendment and growing maize, vegetables and other crops. They planted experiments comparing maize production when organic residues were applied to the soil that belonged to the four classes identified in the decision tree. This certainly led to an increase in understanding of the principles of resource quality and decomposition. For instance, farmers picked fresh green leaves of hedgerow plants little by little and incorporated them into compost heaps to speed up decay and get hotter. A hot compost "cooks" faster. After the experiments, participating farmers also knew that hot composts comprising resources that break down easily took shorter periods to "cook well".

Nitrogen-rich organic residues were in very short supply for these farmers. The most popular use of nitrogen-rich organic materials was with tomatoes and cabbage that fetch a good price at the market. The major problems identified with using organic residues as soil amendments were the extra work involved, and the lack of sufficient quantities, particularly of the types of organic material suitable for immediate application. There were also competing uses for residues poor in nitrogen such as maize stover: one farmer proposed "Give me a cow, I will feed it and

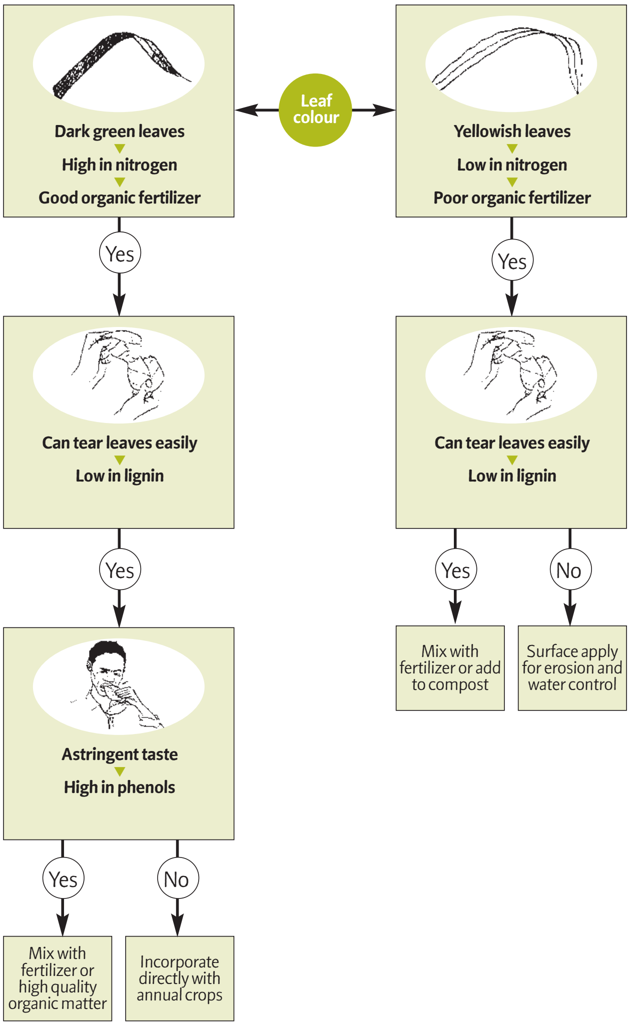

Figure 2. A pictorial translation of the decision tree (IIRR, 1998).

use its manure to do soil fertility management!" Maize stover was used as fuel for cooking, particularly by poorer households. Farmers with sufficient quantities of poor-quality organic materials used them for bedding for cattle and thus eventually adding to the manure heap, or for mulch to assist in soil conservation. The farmers also observed that more succulent and fibrous leaves or material such as sisal and plants belonging to the genus *Euphorbia* decayed slowly and were hard to crush. They were also difficult to compost and therefore of little use for nutrient management. From their experiments, the farmers concluded that it was useful to know how to manage their organic residues alongside the mineral fertilizers that are in short supply and difficult to get hold of. As farmers learnt new skills and gained better perspectives on research knowledge, they increasingly changed their old practices such as burning stover.

Understanding the concepts

Microorganisms, bacteria and fungi are responsible for breaking down all types of organic residues to release the nitrogen they contain –the process of "nitrogen mineralisation"– and make it available in a mineral form that can be absorbed by plants. When micro-organisms break down organic material that provides a lot of energy, as sugars or other carbon compounds that are rapidly broken down, then they need more nitrogen to grow than is released from the organic material itself. To satisfy their hunger for nitrogen the micro-organisms absorb this extra nitrogen from the soil, in a process known as "nitrogen immobilization". We often talk of the carbon-to-nitrogen ratio as being an important indicator of whether a plant residue will make a good organic manure. When the organic materials are rich in nitrogen (when the C-to-N ratio is less than 25) there is "net nitrogen mineralisation". Conversely, when the rates of nitrogen immobilisation are faster than nitrogen mineralisation (when the C-to-N ratio is greater than about 25), there is "net nitrogen immobilisation".

Some other aspects of the "quality" of organic residues are also important. Woody twigs and branches and older leaves break down more slowly than young green leaves. This is partly due to the wider C-to-N ratio, but the rate of breakdown is also strongly influenced by the greater proportion of lignin in woody materials. Another aspect of organic residue quality is the presence of secondary compounds in the leaves, such as tannins. These are complex molecules that slow down or prevent decomposition and release of the mineral nitrogen by binding to nitrogen-rich proteins when the leaves are cut.

Earthworms, termites and other soil animals help to break down plant material, but the role of the earthworms is to render the residues into small pieces. The micro-organisms are able to attack plant residues more easily if they are first broken into smaller pieces, so decomposition is faster when the plant residues are broken up. Plant residues that are woody are harder to break up into smaller pieces and decompose more slowly because of this. The focus is on nitrogen as few plant materials contain enough of the other major nutrients, phosphorus and potassium, to be important sources of these nutrients for crop production.

Test the principles behind the decision trees yourself

Many farmers are now trying out these ideas, and experimenting. When you grow maize plants, you could try it too – add some green manure biomass (rich in nitrogen) in some plots and add maize or wheat straw in some other plots. As a check, sow some plots with maize but do not add any extra organic matter here. You could also include a plot with some mineral fertilizer added for comparison. The plants growing in plots to which straw is added will be clearly more yellow and less vigorous than if they are fed with the green leaves.

Decomposition and nitrogen release are determined by the quality of organic matter which regulates their susceptibility to attack by microbes. This explains why some leaves just vanish when they fall to the ground while maize stalks can remain in the field a year after they were turned into the soil. Farmers can use these concepts to make decisions as to the best ways to manage organic resources for fodder, for nutrient supply, for composting or for mulch.

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Adoption of green manure and cover crops

Roland Bunch

Worldwide, green manure and cover crops (gm/cc's) have proven to be a successful technology for maintaining soil fertility and controlling weeds. The numerous advantages of gm/cc's have led to their widespread adoption in many parts of the world. In other areas, however, farmers have been reluctant to adopt these crops. Moreover, farmers are also known to have abandoned traditional systems. The question is why the introduction of gm/cc's has been a success in one area, while similar programmes have failed in others? Under what conditions can we expect small-scale farmers to be interested in growing cover crops?

Farmers clearing a field with Mucuna in Veracruz, Mexico in preparation for planting maize. Photo: IDRC

After 20 years of experience with gm/cc systems around the world, I would like to discuss the main conditions for adopting green manure and cover crop systems. The following conclusions are based on experiences with 140 different systems, involving 41 species. Sixty percent of these systems have basically been developed by farmers themselves, which shows how appropriate these systems are for farmers and how interested farmers are in them. This article summarises some of the lessons learned from my experiences with programmes and organisations that have been successful in introducing sustainable gm/cc systems.

Opportunity costs

Green manures or cover crops should be grown on land that offers farmers few other opportunities such as income, food, fodder, etc. Generally, farmers are not interested in planting something that only fertilises the soil when the same land could be used for either subsistence or cash crops.

This may seem to impose many restrictions for growing gm/cc's, but in fact we are finding more and more places and times when they can be used:

- If the gm/cc does produce a valued food, it can be grown in any way that fits into the system like any other crop.
- The gm/cc can be grown intercropped with another food for example jackbean with maize or cassava, or perennial peanut with coffee. This is presently the most popular niche for introduced gm/cc systems.
- The gm/cc can be grown on wasteland or on fields under fallow. Suitable species for these areas are gm/cc's that can survive on very poor soils, such as jackbeans, tephrosia, or particularly hardy trees. Farmers in Vietnam, for example, seed *Tephrosia candida* into their first year fallow, thereby reducing the normal five-year fallow to just one or two years.
- The gm/cc can be grown during the dry season, planted after the normal crops like the ricebean/rice system in Vietnam, or intercropped with the normal crop and then allowed to grow through the dry season such as the sweet clover/maize system in Mexico. It can also be planted as a relay crop amongst rainy season crops at the end of the wet season to take advantage of the moisture still in the soil, such as the cowpea/maize and lablab/maize systems in Thailand.
- The gm/cc can be grown under fruit trees, forest trees or almost any perennial crops. In this case, particularly shade-tolerant species, like jackbeans or *Centrosema pubescens* are chosen.
- Other small, occasional niches can be found, such as during periods of frost (lupines, such as tarwi, often do well), in extremely acid soils (velvet bean or buckwheat), or during very short periods of time (*Sesbania rostrata*).

Jackbean (*Canavalia ensiformis*) is probably the second most widely used introduced green manure and cover crop. It is resistant to drought, poor soils, insects and diseases and is capable of surviving and growing well in the worst conditions. The jackbean can be used during the dry season and in very marginal environments where crops will not grow. It has an ability to fix large amounts of nutrients and is also capable of helping wastelands to regenerate.

Cash costs

Growing green manure and cover crops should involve minimal, or no cash costs. This implies that farmers should be able to produce their own seed year after year, and that these crops should be resilient to disease or insect problems. Preferably gm/cc's should save farmers money. They can reduce the amount of money farmers spend on chemical fertilisers. In addition, they can lead to a reduction in or even a total elimination of herbicides. Some species can also be substituted for certain chemicals: the velvet bean is a wide-spectrum nematicide, and sunnhemp (*Crotalaria ochroleuca*) can be used to control grain storage pests.

Labour demand

The gm/cc selected should not lead to an increase in the amount of work farmers have to do. In fact, when intercropped, gm/cc's can save on labour because they can shade out weeds. This reduction in labour required for controlling weeds can in many cases counterbalance the labour needed for planting and cutting the cover crop. Furthermore, farmers can often be partially motivated to plant gm/cc's by the prospect of never having to plough or hoe their fields again: the technology offers the possibility of moving to a zero till system.

Other benefits

The gm/cc's chosen should provide at least one major benefit other than improving the soil. Farmers seldom choose gm/cc's because of their effects on the soil fertility. Usually, farmers are motivated by the potential of gm/cc's to support food production (which usually has a high priority) or to control weeds. The most commonly used gm/cc's, such as pigeon peas, common beans, soybeans and scarlet runner beans are grown for human food. Velvet beans (*Mucuna* spp.), usually not eaten by humans, are also popular cover crops, probably because of their ability to smother aggressive weeds and effectively control nematodes and several plant diseases.

Experiences with projects introducing gm/cc's show that systems that produce benefits other than soil improvement tend to last longer and continue after the "project" has come to an end. This can partly be explained by the fact that soil improvement is a long-term process, which is not immediately noticeable to farmers. The long time that it takes for positive results to emerge is an obstacle to the more widespread adoption of gm/cc's. Therefore, it is often preferable to promote gm/cc's for reasons other than soil fertility. Thus, whenever possible, we should choose gm/cc species that can be eaten, fed to animals or provide some other benefit which farmers need. For example, farmers grow scarlet runner bean (*Phaseolus coccineus),* intercropped mostly with maize, for the edible bean, even though they also realise its importance for conserving soil fertility.

Finally when considering the introduction of gm/cc's, the demand for the products of green manures and cover crop should also be considered. The demand may not be very great if people do not like to eat beans or sprouts, when farmers only have few animals to feed, or when they have already sufficient fodder for the animals.

Existing farming systems

Green manure and cover crops must fit into the existing farming systems. At least for the first few years these crops will be seen as much less important than food or cash crops. They will have to be adjusted to fit into the existing farming system, not the other way around.

Furthermore it is important to understand when, and to what extent farmers would prefer slow maturing tree species and when farmers would prefer fast maturing, less woody and shorter statured plants in their fields. Planting trees as improved fallow is only an option if farmers already have fields under fallow: otherwise it will be too expensive. Whether farmers would prefer a gm/cc system above a tree based system will depend on the relatively demand of the products of both systems. If farmers have rights or gain rights to land by planting trees, they will probably prefer tree-based improved fallow technologies above gm/cc's. Furthermore, many tropical crops do better with a light shade (say 20 to 30%) than with either a heavy shade or no shade at all. Thus, "dispersed tree" systems can very often be ideal for crop growth. And, of course, a dispersed tree system provides a better environment for gm/cc's than total sunlight.

In Brazil, gm/cc's are widely used by farmers with landholdings up to 100,000 hectares. On the other hand, gm/cc's are useful for resource-poor farmers as well, provided that they have sufficient land to allow the incorporation of gm/cc's without affecting the regular cropping system. If farmers have sufficient land to practise shifting cultivation with long fallow periods, farmers may not be interested in gm/cc's.

At farms with little land, the use of the land is often so intensive that there is virtually no time or place when the opportunity cost is very low. In these cases, farmers may be better off using compost or buying soil amendments.

Specific characteristics

Green manure and cover crop species should fit the available niche(s). In general, good gm/cc species should have the following characteristics: easy establishment; vigorous growth under local conditions; ability to cover weeds quickly; and the ability to either fix plenty of nitrogen or concentrate plenty of phosphorus. They should be resistant to insects, diseases,

The role of gm/cc's in rehabilitating degraded land

Green manure and cover crops can contribute to the rehabilitation of degraded lands and the restoration of wastelands in various ways. The most important impacts and effects of gm/cc's are listed below.

Increased organic matter and nutrient cycling. The organic matter from gm/cc's has, in turn, a whole series of positive effects on the soil, including making soil nutrients more accessible to crops. For example, in acid soils phosphorus may be four to five times more available to plants when surrounded by organic matter.
Nitrogen fixation. Organic matter often adds significant quantities of nitrogen to the farming systems. Many, if not most, of the widely used legumes are capable of fixing more than 75 kg/ha of N, while a few species fix a good deal more: the velvet bean can fix 140 kg/ha/crop, the jackbean up to 240 kg/ha, and Sesbania rostrata is capable of fixing 400 kg/ha.
Weed control. Intercropped with food or cash crops, green manure/cover crops are important for controlling weeds and consequently they reduce farmers' labour requirements and costs. Additionally, gm/cc's are also known to be able to control very aggressive weeds. In West Africa, for example, velvet beans (Mucuna spp.) are largely grown to control Imperata grass.
Soil conservation. The soil cover provided by the green manure/ cover crop protects the soil from erosion.
Improved soil moisture. The soil cover plus the increased infiltration and water holding capacity brought about by the organic matter, often increases the crops' resistance to drought.
Zero tillage. After a few years of heavy applications of organic matter from gm/cc's farmers can move to zero tillage systems that retain very high levels of productivity.
Control plant diseases and nematodes. Gm/cc's can reduce, and in many cases totally eliminate, the use of pesticides.

Green manure and cover crops can play an important role in the restoration of wastelands. Their use can result in such a significant increase in soil fertility that it is possible to speak not just of soil conservation, but of soil restoration and soil recuperation.

Extremely low or irregular rainfall, extremes in soil pH, severe drainage problems, or combinations of these problems, which are all too common on the farms of resource-poor farmers, will reduce the growth of gm/cc's, thereby reducing or destroying their impact. Through the years, we have learned how to overcome an increasing number of such problems, often using gm/cc's species that are particularly resistant to specific problems. However, such solutions are often achieved at the cost of reduced biomass production, reduced nitrogen fixation, and reduced additional benefits.


Nodules on the roots of Mucuna pruriens formed by Rhizobium soil bacteria. Photo: IDRC

grazing animals, bush fires, droughts, or any other problem they may have to face within the desired system. They should also have multiple uses, and should produce viable seeds in sufficient quantities for future plantings. If they are to be used for intercropping, they should tolerate shade and fit in with the cycle of the main crop(s).

Some species that have been introduced may establish themselves so successfully that they become pests. Great care should be taken not to introduce potential pests. Known candidates are common kudzu (*Pueraria lobata*), tropical kudzu (*Pueraria phaseoloides*), and even perennial peanut (*Arachis pintoi*) and perennial soybean.

The more ecological deterioration that has taken place, especially as far as soil quality and rainfall regularity are concerned, the more limited will be the selection of gm/cc species that grow well. Nevertheless, in a year or two, when these gm/cc's have improved the soil somewhat, farmers can often graduate to less hardy varieties that produce more subsidiary benefits.

Jicama (Pachyrhizus erosus) is a food crop that can also be used as a cover crop. Photo: CIDICCO

Conclusions

We have learned, while trying to apply these rules in many different situations around the world, that finding acceptable, widely adopted systems for (or preferably, with) farmers requires a great deal of flexibility and creativity. No textbook is able to tell us exactly what technology could or should be used in any particular case. We have to be open, listen to and learn from the local farmers, and then work together with them to find out which species and which systems will best fit their particular situation.

Generally, the most successful way of doing this is to first observe the local farming systems, and look for an appropriate niche: traditional crops among which gm/cc's could be intercropped, times during the growing season when lands are left idle, or perennial crops around which gm/cc's can be grown. In the absence of these possibilities, one can try growing the gm/cc during the drier seasons or as improved fallow. After identifying the best niches, one should select for experiments those species that are known to function best in those niches that will provide the benefits most desired by the farmers with the least amount of labour.

In order to introduce green manure and cover crop systems successfully, we need a much better understanding of existing systems. We need to understand the geographical extent of present systems, the rates of adoption or abandonment, and the reasons why gm/cc's have been accepted or rejected. At the moment research into finding ways that the most common gm/cc's can be used to feed different animals is a high priority. Innovative associations of gm/cc's need to be investigated as well as the associations between these and common crops. We also need to know a good deal more about the theory of inter-cropping and the mechanisms by which gm/cc can lead to zero tillage. What are the minimum requirements to move to zero tillage, and how can these be easily achieved under different conditions? New gm/cc species need to be found which can respond to farmers' needs. Virtually all of this research can and should be done in the field through participatory processes. ■

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Table 1: Characteristics of some important GM/CC species

Common name	Scientific name	Resistance to shade	Resistance to poor soil	Resistance to drought	Controls weeds	Other uses
Velvetbean	Mucuna spp.	3	3	3	4	Medicine, animal feed, human consumption (when processed)
Jackbean	Canavalia ensiformis	4	4	4	3	Human consumption (tender pods)
Cowpea	Vigna unguiculata	3	3	Some vars. 4	3	Human consumption
Pigeon pea	Cajanus cajan	3	3	4	2	Animal feed, human consumption
Tephrosia	Tephrosia vogelii or T. candida	2	4	4	2	Insecticide

4 = extremely good 3 = good 2 = fair 1 = poor

R2.3
ARTICLE 3

Direct sowing through a cover of crop residues, avoiding ploughing and minimising soil disturbance: soybean grown under CA in Brazil. Photo: Sally Bunning

Planting concepts and harvesting good results

José Benites, Sandrine Vaneph and Alexandra Bot

In large parts of Latin America, Asia, Eurasia and Africa soil tillage by plough or hoe is the main cause of land degradation leading to stagnating or even declining production levels and increasing production costs. It causes the soil to become more dense and compacted, the organic matter content to be reduced and water runoff and soil erosion to increase. It also leads to droughts becoming more severe and the soil becoming less fertile and less responsive to fertiliser.

In the early seventies, farmers in Paraná, Southern Brazil, recognised that continuing soil erosion and declining crop yields were forcing them to abandon their land and move into a marginal existence. Their first attempt at changing this trend was to rigorously adopt conventional terracing systems. The mixed and often disappointing results led them to tackle the problem of erosion at its source, considering the direct impact of rainfall on the bare soil. They abandoned the plough, broke their compacted soils, introduced cover crops, stopped the burning of crop residues and developed cutting rollers to turn crop residues and cover crops into mulch. This mulch layer eliminated rainfall impact on the soil, reduced the speed and quantity of runoff and virtually eliminated soil erosion. It also significantly increased soil fertility and yields, and reduced the labour and cost of land preparation (Hercilio de Freitas 2000, see also ILEIA Newsletter Vol.11, No.3, pp.16-17).

This was in the early nineties, at the beginning of the Zero-Tillage (ZT) movement in Latin America. At that time '*conservation*'-, '*reduced*'-, '*no*'- or '*zero*'-tillage or '*direct planting*' in combination with herbicides was already being practised by commercial farmers, mainly in the USA. But it was only after ZT was combined with cover crops and crop rotation, adapted to tropical conditions, and improved herbicides and special equipment were developed, also for small farmers, that the tremendous benefits of this approach were widely appreciated and it spread faster.

At present, ZT is being practised on about 60 million ha, mostly in Latin and North America. In Latin America, particularly in Brazil, Argentina and Paraguay, some 25 million hectares have been converted to ZT in the past ten years. As the approach has become far more comprehensive than simply ZT, it is now being referred to as Conservation Agriculture (CA) by FAO and other organisations (see also LEISA Magazine Vol.17, No.3, p.22).

In Latin America, farmers, their organisations and networks took the lead in the development of CA. Government support was initially limited as ZT was not an officially recognised technology and researchers, extension agents, trainers and policy makers were reluctant to accept new ideas. Now, all this has changed and CA is developing fast due to effective collaboration between farmers, private enterprise, research and extension. CA has long passed the stage that it was only suitable for grain crops, like maize, beans and soy. Now, crops like sugarcane, cassava, tobacco, onion, tomato, cabbage and lettuce are all successfully grown under CA.

CA also fits into an increasing number of cropping conditions of large and small farmers in the humid and dry tropical, semi-tropical and temperate climate zones in Latin America, Africa, Eurasia and Asia. The FAO is playing an important facilitating role in promoting and further developing CA, among others, by its field projects, by actively supporting regional CA networks and by providing information on CA through its publications and web site. This article provides an overview of principles, practices, potentials, constraints and methodologies. The articles on p. 10 and 11 present two FAO-supported cases of CA in Honduras and El Salvador. The article on p. 13 discusses the perspectives of CA in Africa. Previous issues of LEISA Magazine have presented approaches similar to CA: New Kekulam zero tillage rice farming in Sri Lanka (Vol.13,No.3,pp.20-21); traditional mulch farming in Burkina Faso (Vol.15, No.2&3, p 37), traditional shifting cultivation and analog agroforestry (Vol.16, No.3); the Rice Wheat Consortium approach to CA in India and Pakistan(Vol.16, No.4, pp.8-10). Other cases can be found in (García-Torres, Benites and Martínez-Vilela 2001).

General principles of CA

Three technical principles are crucial in CA:

- ***No mechanical soil disturbance*** – *direct seeding or planting*
- ***Permanent soil cover*** – *particularly with the use of crop residues and cover crops*
- ***Judicious choice of crop rotations*** – *multiple cropping, agroforestry and animal integration*

The permanent soil cover provided by growing crops, crop residues or mulch not only protects the soil from the physical impact of rain and wind, but also stabilises the soil moisture and temperature in the surface layers. This zone thus becomes a favourable habitat for a number of organisms, including plant roots, worms, insects and microorganisms such as fungi and bacteria. This soil life uses the organic matter from the soil cover, recycling it into humus and nutrients, and contributes to the physical stabilisation of the soil structure, allowing air and water infiltration and storage. This process, which can be called "biological tillage", strongly enhances soil and water conservation and soil fertility. Mechanical tillage is avoided in order to maintain soil life and soil structure, and to reduce mineralisation of soil organic matter. A varied crop rotation is important to avoid pest and disease problems, improve soil conditions and make full use of the entire soil profile and the synergetic and complementary interactions between different plant species. Green manure/ cover crop species (leguminous and non-leguminous) that are part of the crop rotation are essential in building up the soil organic matter content. The soil cover also provides new habitats for natural enemies of pest and disease organisms. It provides a physical barrier to weeds and releases allelopathic substances that reduce weed germination. Thus a healthy soil which offers optimal physical, chemical and biological conditions for the growth and reproduction of plants is created.

Box 1. Key features of CA systems

- No ploughing, disking or seed bed preparation
- Green manure / cover crops are integrated into the cropping system
- Crop, weed and cover crop residues applied as mulch protect the soil permanently
- Direct seeding or planting
- No burning of crop residues or fallow vegetation
- No uncontrolled grazing
- Nutrient cycling through the biomass in and above the soil
- Surface application of lime and fertilisers
- Specialised equipment for seeding and mulch management
- Continuous use of cropland
- Crop rotations and cover crops are used to maximise biological controls

Specific practices

Many traditional shifting cultivation systems follow the above principles of slash and mulch. Uncontrolled burning (slash and burn) and grazing, however, works against these principles. There are no blueprints for the development of new CA systems and the general principles and key features (see box 1) have to be adapted to each specific agro-ecological, socio-economic and cultural context. The success of such a new system depends entirely on the creativity and flexibility of its practitioners in developing management practices suited to their particular situation and needs. Traditional practices and species, which are adapted to the local context, but abandoned due to reasons of low productivity, are often re-introduced with good results. Agrochemicals are not excluded, but low or decreasing quantities are used efficiently. CA often includes Integrated Soil Fertility Management (ISFM), Integrated Pest Management (IPM), Integrated Weed Management (IWM), agroforestry and crop/livestock integration, for which the three principles provide an excellent basis. The integration of trees and livestock into the system is especially important. CA can come close to or be completely organic.

Benefits are many

Permanent vegetative soil cover ***strongly prevents soil erosion*** and reduces the need for other soil and water conservation measures, bunding, terracing, etc. The increased soil organic matter content allows more water and nutrients to be stored in the soil profile, so ***more soil moisture and nutrients are available for plant growth***. The excess water filtrates to deeper soil layers, ***recharging groundwater supplies*** and reducing floods and sedimentation of waterways downstream. The water conserving effect of the soil cover and the increased organic matter result in an ***economisation of irrigation water***, as is shown in table 1.

With time, the accumulation of soil organic matter and the increased activity of soil micro-organisms lead to ***higher efficiency of organic and inorganic fertilisers*** and thus allow lower application rates. This saves costs and increases the profitability of in-organic fertilisers, thereby making them affordable to more farmers.

Increased soil moisture and soil fertility favours root penetration and development, which in turn ***boosts biomass production and crop yields***. CA is a successful strategy for ***ecological intensification,*** among others ***of shifting cultivation and slash and burn systems,*** which can evolve into permanent agroforestry systems, while burning is abandoned.

CA allows ***early and timely planting*** due to the absence of tiresome land preparation activities. The effects of the soil cover result in an agricultural system that is ***less vulnerable to drought, heavy rainfalls or other natural disasters.***

Also ***the risk, scale and frequency of weed, pest and disease infestation are reduced considerably***. Where chemical pesticides or herbicides are applied in CA, the amount needed often decreases with time as farmers gain skills and new ecological balances are established. Compared to conventional tillage, ***the use of chemical pesticides and herbicides is less*** in CA.

The improved workability of the soil and less agronomic activities during the production cycle ***reduce the labour requirement substantially*** (see table 4, p.12). This is especially important for those who rely only on family labour and in areas where labour is becoming a constraint because of deaths and diseases. The reduction in the on-farm labour requirement allows ***farmers*** to ***diversify their activities***, including processing of agricultural products, and thus improve their incomes. Besides the reduction in

Table 1. Economy of irrigation water through soil cover (Pereira, 2001).

Percentage of soil cover	0	50	75	100
Water requirement (m^3 ha^{-1})	2660	2470	2090	1900
Reduction in water requirement (%)	0	7	21	29
Number of times irrigated during season	14	13	11	10
Number of days in between irrigation	6	6	8	9

Table 2. Increase in yield and farm income (in monetary units; CA=Conservation Agriculture)

	Conventional Agriculture	CA Year 1	CA Years 2-4	CA Years 4-6	Year 6 and onwards
Gross output	2000	1800	2200	2300	2400
Total variable costs	1400	1300	1200	1100	1000
Gross Margin	600	500	1000	1200	1400
Total fixed costs	200	200	200	200	200
Net farm income	**400**	**300**	**800**	**1000**	**1200**

(FAO, in print. Conservation Agriculture. What you should know about... economic aspects of Conservation Agriculture. Training module. AGLL. FAO Rome.)

labour, the ***cost for land operations and maintenance of tools and equipment are also reduced***. Even where mechanical traction is used, CA leads to ***considerable savings in the use of fossil energy***. As CA also strongly contributes to carbon sequestration due to the increase of biomass in and on the soil, it could when applied at large scale, provide ***a major contribution in controlling global warming.***

All this contributes to ***increased and more stable yields and revenues (up to double or even triple)*** which build up during a period of 2-6 years. Diversification of agricultural production also plays a role in ***improving the farmer's livelihood: less risks, increased income, improved diet, etc.***

CA provides a truly sustainable production system, not only conserving but also enhancing the natural resource base and ***increasing biodiversity*** without sacrificing yields at high production levels. Therefore CA is a major opportunity that can be exploited for achieving many objectives of the international conventions on combatting desertification, on biodiversity and on climate change.

Constraints and challenges

Conversion from conventional tillage to CA is not simple and poses many constraints that need to be resolved, demanding time, effort and money. It may include costs for purchasing specialised equipment and agrochemicals, possible temporary income decreases until the new dynamics are established, and a learning process by the farmer to acquire higher management skills. For many (small) farmers, a general lack of financial resources and lack of access to equipment, chemical inputs or green manure seeds can be serious limiting factors.

Tenure may also be a constraint in situations where most of the land is collectively managed and where land is accessible to multiple users often having contradictory interests in terms of land use, for example pastoralists and farmers. Farmers who have insecure tenure may be reluctant to adopt CA even though they see the benefits, because improving the soil productivity increases the risk of losing the land to more powerful persons in the society. This is a major problem for landless persons and female heads of households.

Pest, disease, weed or soil fertility problems could occur in the transition stage when the system has not yet stabilised ecologically. This may require the use of chemical pesticides, herbicides or fertilisers for which money could be a constraint. In moist areas for example, a major issue raised by the permanent soil cover could be pest and disease management. The crop cover may harbour small animals such as rats or snakes. In drier areas, the lack of biomass due to water or nutrient shortages and other uses of the biomass (livestock feeding, cooking) is often a major issue. Where population density is low and agriculture is marginal, availability and the cost of equipment and agrochemicals is a constraint. Social and cultural acceptability may also be a problem where CA differs substantially from the indigenous or conventional system.

Before starting with CA, it may be necessary to eliminate some major effects of degradation, such as compacted soil layers, plant nutrient deficiencies or heavy weed infestation. Subsoiling of compacted and degraded soils can, due to higher water infiltration, result in immediate yield increases of up to 30%, but may be too costly for small farmers.

Conversion from conventional tillage to CA calls for a drastic change of thinking. CA is based on agro-ecological processes and systems which require farmers to think in terms of ecological concepts such as soil as a living system, plant communities, nutrient flows, pest – predator and animal – crop – soil relations, etc. If farmers are unable to radically change their thinking and vision on farming, they will not succeed in making CA work effectively. This is not only true for farmers but also for technicians, extensionists and scientists.

Farmers who depend on their local resources may have a lot of traditional / indigenous knowledge that fits with CA. Often, extensionists and researchers find it difficult to accept indigenous knowledge and learn from and with farmers. For them, shifting to the concept of CA and a participatory way of working means a tremendous change. The resistance to change of researchers, academics and advisors can be much greater than that of farmers.

Box 2. "Friends of the Land" clubs in Brazil

In Brazil, the main obstacles for farmers in the adoption of Zero Tillage were the lack of knowledge, information and technical support. These obstacles were overcome through the activities of "Clubes Amigos da Terra" (CATs), non-profit, non-commercial and non-political farmer organisations. The operational basis of the CATs is farmer-to-farmer exchanges of experiences on a monthly basis and organisation of promotional events, such as field days and debates. CATs also organise on-farm research and pilot projects with the support of other organisations. An important factor for success has been the assistance which medium and large farmers, through individual CATs and the Brazilian Federation for Direct Planting, have provided to small farmers wishing to adopt ZT. Private sector support was fundamental to the expansion of ZT as well. In South Brazil, where ZT by small farmers is well developed, there are more than ten manufacturers specialising in ZT machinery for small farmers. Both in South Brazil and Paraguay, ZT systems that eliminate the need for herbicides have been developed, especially for small farmers.

Recently, the Landcare movement in South Africa adopted an approach similar to CAT in Brazil, advocating the establishment of local Landcare Groups which would conduct situation analysis, broaden their strategic understanding with a visioning process of CA, and then undertake participatory land use planning.

Farmer groups crucial for CA

Access to information, cover crop seeds, equipment, training and technical support is a prerequisite for successful conversion to CA. In addition, financial support, especially for small farmers, is often a major requirement to catalyse the conversion process. But, one of the lessons learned from Brazil is that new technologies spread fast only when farmers feel the need to change their practices and when they take the lead in technology adaptation and innovation. Simple extension of the message, even coupled with demonstration, usually will not suffice. Also, successful improvement of land husbandry depends not just on the motivations, skills and knowledge of individual farmers. The formation of farmer groups and associations or, even better, building on existing and active groups for testing and adaptation to local contexts and learning from shared experiences is crucial for CA to take off. In Brazil such groups have become action groups, transmitting the new ideas and technologies from farmer to farmer, stimulating and supporting members to make the change (see Box 2). In addition they have also become important local pressure groups, managing to obtain improvements at institutional and political level.

Strategies for conversion to CA

Specific conversion strategies are needed to make conversion to CA attractive and affordable to farmers. In Latin America, building up soil organic matter content in the soil with intercropped green manure / cover crops (associated with the normal cash or subsistence crops) over a period

Box 3. Principal mechanisms for mass conversion to CA

- farmer-to-farmer exchange
- extension activities
- commercial and NGO-sponsored events
- small farmer pilot projects
- technical assistance/promotion activities of private sector
- private and co-operative technical assistance
- NGO/government/private-sector publications
- press and television reports
- small financial inducements

of one to three years before moving to ZT is the strategy followed by most farmers. In this way the conversion takes place without loss in productivity, while costs (for tillage and equipment) already drop considerably (Rolando Bunch, Fallow Net email discussion on CA).

Farmers may have their own specific reasons for wanting to change their farming practices. These reasons can vary from community to community and from one social group to another within a community. This calls organisations working with farmers to offer specific entry points. Saving labour, increasing yield, reducing costs, drought proofing, improving health or the livelihood system in general can be appropriate entry points to start CA. It must be the farmers themselves who decide on trying out or transferring to CA and which entry point is most important for them. They should also decide on the use of external inputs: choosing between herbicides and mechanical weeding, and using fertilisers and lime to correct initial soil imbalances. Good information on potential benefits, opportunities and constraints is a prerequisite for farmers in making their choice.

Finding the right approach of facilitating a farmer-driven participatory conversion and technology development process while ensuring the communication of a very straight-forward technical message is challenging. It requires the support of convinced and capable extension workers and researchers. Often, low-cost or ecological options can be found for adaptation to the local context and resolving conversion problems, for example weed control with hand tools, cover crops and crop rotations; use of manure and biological nitrogen fixation; home-made "soups" for disease control; compost starters etc. (Barber 1999). Sometimes new innovations are needed.

CA started in many countries as a farmer-driven adaptation of a production system. But researchers and extension workers from both public and private sectors have played an important facilitating role in reaching a critical mass of farmers and generating knowledge and adaptations to the system as a whole or to equipment in particular. In addition the process has drawn sectors together and allowed the development of coherent integrated strategies and approaches (see Box 3) addressing crops, livestock, land and water resources, as well as infrastructure, marketing, education etc.

Involving the private sector

The large-scale shift to CA in Brazil and Argentina was possible among others due to close collaboration between innovative farmers and the private sector to develop and disseminate appropriate equipment. CA is challenging the existing private sector companies and local craftsmen/artisans to support the transition to CA systems. In particular, the testing, manufacturing and provision through local markets of required tools and implements. The same applies for cover crop seeds and associated herbicides plus spraying equipment, in case chemical weed management is chosen (see Box 4).

Exchange and networking

Access to information is very important in reaching a critical mass of CA practitioners, both within a country and between countries and organisations. Part of the information can be made available in the form of selected case study material describing CA experiences under different conditions. Researchers can gather in-country information on, for instance, validation of different cover crop species and testing and adapting of hand and animal drawn equipment.

The transfer of the concepts, principles and technologies of CA needs network interchange within and between countries, so as to facilitate sharing of known solutions to problems identified during the continual learning process. Such networks can accelerate the advancement of knowledge and techniques being steadily accumulated by both national institutions and community groups in their efforts to reverse land degradation on a global scale. For this purpose several regional networks -RELACO, ACT, SACAN and ECAN- have been founded in Latin America, Africa, South Asia and Central Asia (see Websites p.30) respectively.

Policy support

CA will only spread rapidly and widely when and where government policies, services and infrastructure facilitate the conversion to these systems. Policy support is needed to adjust legislation and to provide an enabling environment to meet the requirements and facilitate the initiatives of local groups and land users. This means an appropriate policy and institutional framework and the provision of incentives (pricing, markets, land reform, security, etc.). Existing incentives and subsidies should not jeopardise the implementation of the system. New incentive measures may be needed to encourage CA uptake, including the identification and multiplication of seeds and supply of equipment through public and private sector involvement. Financial support alone cannot boost a CA programme. It is essential to make the general public, decision and opinion makers aware of the social benefits of the adoption of these practices in order to gain the government's support for natural resource management initiatives of farmers.

Finally, international organisations such as World Bank and FAO, and OECD countries in their own right, should encourage a vigorous international and regional media campaign emphasising the importance and relevance of CA as an entry point to the process of rural poverty alleviation, food security, and environmental protection. Development of CA can only be achieved by integrated action at farm, community, national and international levels.

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Box 4. Development of equipment for CA in small farms

Even in 1990, there were few small farmers working with CA in Brazil. Although the general principles were broadly applicable, the planting technology for manual and animal traction had not been developed. It was pioneer research and small manufacturing firms, which resolved the problems of adapting the planting technology in direct collaboration with farmers. Equipment for direct seeding in mulch (e.g. jab planter or animal driven direct seeders), management of vegetative cover (e.g. knife rollers and slashers), spraying of herbicides (e.g. adapted knapsack sprayer) and mini-tractors were thus developed for small farmers (see illustrations on cover, p.3,13,14). Collective purchase and use of such equipment was stimulated, as CA allows for greater flexibility in the time of sowing.


Scenes from the Guangdong area before (left) and after (right) ecological restoration. Photo: Jianwu Wang

Agroecological restoration in Guangdong

Peter Riggs

In 1980, Guangdong Province became one of China's new Special Economic Zones, encouraging foreign investment in manufacturing and light industry. Today, the province's capital is a major banking and financial centre but agriculture continues to contribute heavily to Guangdong's GDP.

The developments of the last 20 years have, however, had a serious impact on the environmental health of the countryside and as a result on the welfare of many farming communities. Several food safety scares over the past few years have also underscored the importance of developing 'new thinking' for this vital sector.

In response, provincial leaders in partnership with Guangdong's agricultural university and its network of extension agents and consumer health specialists, have risen to the challenge.

Guangdong is now dramatically re-orienting its food production and agricultural research systems, putting long-term environmental sustainability, farmers' welfare, and the promotion of chemical-free and/or organic agriculture at the centre of provincial rural development efforts. Guangdong is skilfully positioning itself to take advantage of rising Chinese consumer awareness of food safety and quality concerns. At the same time it is also securing the position of the province's agricultural export sector under the new international rules that China must now follow as a result of its accession to the World Trade Organisation.

Guangdong has never been a "rice bowl" in the sense of committing vast acreage to growing staple grains. Rather, Guangdong has long enjoyed comparative advantage in the production of sub-tropical fruits, sugar cane, as well as farmed fish and horticulture products. The flat and well-watered Pearl River Delta region in southern Guangdong was famous for the "dike-pond" agriculture system, in which farmers devote the major share of their acreage to ponds for raising fish, particularly carp, and recycle pond wastes onto the bunds and dikes fringing the ponds to grow citrus fruits, sugar cane, pineapples, and mulberry trees for feeding silkworms. But 80% of Guangdong's land is hilly, and in this sub-tropical climate zone the soils are generally poor and easily eroded. The "Great Leap Forward," the Cultural Revolution and insecurity over land tenure in the late 1970s and early 1980s, all accelerated deforestation in Guangdong Province leading to alarming levels of soil erosion. Indeed, control of soil erosion has been a major concern of the Guangdong government for the last twenty years.

Today, Guangdong is one of China's wealthiest provinces and has the resources to deal with the alarming legacy of environmental damage caused by the policy instability of earlier periods. Increased wealth has also meant that the priorities of local consumers have shifted and they are increasingly concerned about food quality and safety.

The major agricultural policy challenge facing the province in the early 1990s can be summarised as follows: How can Guangdong meet the food production and food quality demands of international markets and a growing number of concerned Chinese consumers, whilst at the same time halting the degradation of the rural land base and reducing reliance on dangerous pesticides and chemical fertilisers?

Research and development

Two institutions have played a key role in Guangdong's agricultural transformation: the province's agricultural university, South China Agricultural University (SCAU) and the Provincial Committee For Science And Technology. Together, they have organised agricultural research and development as well as complementary research on large-scale land restoration.

By the 1980s, soil erosion had reached such alarming levels that in many cases the province opted for, or had no choice but to implement, "engineering" solutions that sought only to stabilise hillsides and watercourses. Bracken fern and pine trees were adopted as "green cover", useful for quickly reducing erosion rates, but not useful as economic crops for farmers. Gradually, the provincial institutes for geography and botany, and the university extension services, sought to integrate farming communities into land rehabilitation efforts. In the 1990s, Beijing authorised local governments in China to auction off degraded hilly lands to the highest bidders. In Guangdong, the bidders included individual farm families, local production co-operatives, or private companies. These "wasteland auctions," as they were called, again focused attention on the productivity-enhancing technologies that could be used to bring these lands into production while keeping soil erosion to a minimum. The wasteland auctions were also an innovation with respect to the rights of landholders. Now, families and enterprises could count on long-term tenure security, which made the construction of terraces both possible and profitable. Consequently, in the last ten years we have seen an immense input of labour and capital into terracing, primarily for the production of fruit trees. First amongst these fruit trees is the lychee, which has brought much prosperity to rural Guangdong.

Orchards

Guangdong accounts for a high proportion of the *global* production of lychee, a much-coveted fruit in China and amongst overseas Chinese. At a number of research stations in lychee-growing areas of hilly Guangdong, SCAU has been involved in developing organic and "high-quality" production lines. Pest management has been a particular concern and research has focused on biological control, promotion of organic fertilisers through on-farm composting, and the inter-cropping in fruit orchards of species that provide a habitat for those "natural enemy" species that keep pest numbers in check. The diversity of production settings resulting from the "wasteland auctions" has been a complicating factor in the design of appropriate extension services; yet at the same time, has helped ensure a wide range of experimental settings.

As more of Guangdong's farmers and agribusinesses become interested in integrated pest management to reduce production costs and to enhance product quality, farmers and farm managers are paying greater attention to the environment in which "natural enemies" of pests can thrive. In the past the practice of clearing all the brush and grass from orchards was widespread, even though farmers had no other explanation than that the bare soil "looked better" than an unruly ground cover. Now, farmers increasingly realise that this under-story provides a good environment for insects what can dramatically decrease the need for spraying pesticides. The new frontier for research now is whether it is possible, and whether it makes economic sense, to pursue inter-cropping of annuals (like peanuts or maize) or Chinese medicinal plants to add another source of income from orchard lands. Already, one can see areas in which trees are planted farther apart to enable this kind of agroforestry approach.

Cutting the legume Stylosanthes guianensis for decomposition on the farm. Photo: Jianwu Wang

The drive to increase soil organic content has led to two further technical improvements. The first is an increased integration of animal production into these farming systems. The excellent price that farmers obtain for lychees has allowed many of them to set up piggeries, or chicken houses, with pig and chicken wastes recycled back to the orchards. Some parts of Guangdong also have a very high adoption of household-level biogas systems, with pig wastes making the major contribution to these systems. Farmers have also found that having "free range" chickens in the orchards has helped reduce pest problems and increase nutrient cycling.

Some municipalities in Guangdong have also experimented, with some success, in recycling municipal wastes back to farms. In the worst cases, municipalities see this as a "low-cost option" for dumping garbage in areas where farmers are desperate for *any* contribution to soil organic matter. Now several large-scale municipal composting facilities are being set up. Odour control, product quality, investment, and urban-rural linkage schemes remain major challenges for these ventures. The question of how to transform urban China's growing solid waste problem, through better waste separation and composting, into a stream of benefits for farm communities is a new frontier for research and development activities.

Sustainable agriculture

Guangdong has developed the technical capacity to reorient its rural sector toward "sustainable agriculture." With South China Agricultural University as the focal point, Guangdong hopes to build the service infrastructure for organic production. There is political will at the provincial, county, and township levels to implement changes in orientation, but in most cases there is still a generally weak understanding of what is required to meet international organic production standards. In addition, there are still a number of issues that urgently need to be addressed.
One of these is water pollution. The continued over-reliance on chemical fertilisers and the increase in concentrated animal feeding operations are wreaking havoc with surface water quality. There is an urgent need to develop organic fertilisers, improve municipal solid waste management (including through composting of the organic fraction of urban wastes) and prioritise the safe handling of livestock wastes. Much of SCAU's research also focuses on the development of botanical pesticides and on the chemical interactions between insect predators and preys.

Another critical issue is the re-tooling of extension services. The move from a centrally-planned economy to a market economy has completely changed the conditions under which the agricultural extension services have to operate. In Guangdong, many extension services have been privatised. A variety of public-private partnerships might be explored, but it is crucial that the worst abuses of the "contract farming" approach found elsewhere in Asia be avoided.

Conclusion

While the immediate driving force behind Guangdong's rural-sector reorientation is a concern for the competitiveness of its agricultural products in markets increasingly concerned with food quality and safety, the goals of the reorientation are much broader than this. They include restoring a degraded land base; maintaining rural communities and reconnecting them with local cultural traditions; and combating severe surface- and ground-water quality problems. To achieve these goals, scientists and planners in Guangdong have become practitioners of *agroecological restoration*, the attempt to "reconnect food systems with ecosystems." Of course, one can see such efforts in other parts of China; but it is in this wealthy southern province where the farm-to-table market opportunities, the "knowledge infrastructure," and the political willingness to innovate have come together most dramatically. Guangdong's changing countryside may hold important answers not just for the future of agriculture in China, but also for rural livelihoods generally, in response to the challenges posed by globalisation.

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Farmer innovations in water harvesting

R2.4

Deborah Duveskog, Charles Mburu and Åsa Forsman

The farm of Alex Ole-Pere is often described as an oasis in the desert. From afar you can see a large Bluegum (Eucalyptus) tree, which would not normally survive in this dry climate. As you approach his farm, there are trees visible on the plains where typically the only vegetation is Acacia bush. Alex is one of the farmers identified as an innovator in the "Promoting Farmer Innovation in Farmer Field Schools" (PFI-FFS) programme in Kenya. His simple yet ingenious idea of a rainwater reservoir to capture run-off water from the surrounding mountains has been spread to other farmers in the area. In addition, his plot now serves as a water reserve for surrounding farmers and pastoralists in the dry season.

Spreading innovations

Africa has enormous resources of rich traditions, untapped knowledge and promising innovations relating to soil and water management. A large number of farmers experiment with soil and water conservation techniques on their own and spontaneously try out new practices, without the direct support of formal research and extension. Like the invention of Alex Ole-Pere, many of these small-scale initiatives have the potential to benefit other smallholders if they are applied on a wider scale. Farmers in drylands often suffer from extension systems that do not function well because of the large distances involved and the marginal nature of arid areas. This often leads to the failure of recommended technologies. Instead of relying on technologies that are often inappropriate and introduced from the outside, there is a real possibility in dryland Africa to build on local resources of knowledge and traditions, and the inventiveness that comes from necessity.

In East Africa in recent years, increasing attention has been paid to capturing local knowledge and initiatives and disseminating this information to other farmers. For example, UNDP and FAO have been working since 1997 to increase the recognition given to indigenous knowledge in agricultural extension by supporting farmer-to-farmer knowledge sharing and the identification and dissemination of local innovations (see Box).

Innovation initiative in East Africa

The Promoting Farmer Innovation (PFI) process is a 10-step guideline to identifying and disseminating farmer innovations. It was developed by a UNDP supported project in 1999. The project was piloted in Kenya, Tanzania and Uganda with the aim of identifying farmer innovators. The ideas of these innovators were disseminated through farmer-to-farmer extension and farmer exchange visits. In Kenya, an ongoing initiative supported by UNDP and FAO known as the "Promoting Farmer Innovation in Farmer Field Schools (PFI-FFS)" project has merged the PFI process with the Farmer Field School (FFS) approach to participatory extension. The objective of the initiative is to facilitate increased interactions between innovators and FFS groups and in this way to stimulate the process of innovation and discovery among farmers. Innovators are identified by FFS extension staff and are often included in the FFS as group members, guest speakers or resource persons. Alternatively, the FFS groups go on study visits to see the innovations.

About 250 farmer innovations have now been identified within the Kenyan PFI-FFS project. Around 40 percent of innovations are related to the efficient use of water resources, including water harvesting, small-scale irrigation and other ways to use surface water efficiently.

Dam building

Alex Ole-Pere is a Maasai who lives in a semi-arid area in southern Kenya. Although the district receives up to 600 mm of rainfall per year, this rainfall is highly erratic and unpredictable. The risk for crop failures due to drought is high. People in the area traditionally depend on livestock, but as it gets harder to sustain large cattle herds on grazing land that is gradually shrinking, more and more people have started to turn to crop production. Alex realised that every rainy season a lot of water from the nearby mountains seemed to be wasted as it raced towards the rivers. He came up with the idea of collecting this rainwater by building a dam. He built a reservoir close to his homestead and constructed a diversion from a local waterway. The diversion directed the flow of water from the stream into the reservoir. The dam, which is about 20 by 30 metres wide, was built by digging out the earth and putting it on the outside of the reservoir.

Alex Ole-Pere next to his reservoir. Photo: Åsa Forsman.

Water collected in this way is used for irrigating vegetables and tree seedlings. While most of the area around Alex's farm appears barren because trees and bushes are continually being cut for firewood, Alex plants more and more trees every season on his plot. Apart from sustaining the crops and trees on Alex's farm, the reservoir also serves the larger community. *"My neighbours normally come to fetch water from my dam in bad times. They can take both for their families and for their livestock. I have enough"*, he says proudly.

Earth banks

Agnes Mughi is a farmer in a very dry zone of Mwingi district. Her farm was suffering from water scarcity and she decided to do something about it herself. The area where Agnes lives is often affected by drought and the soil is compacted and eroded. However, her farm now appears green and productive all year round, in sharp contrast to the surrounding area. By using her own creative ideas, Agnes tamed the floods from a nearby seasonal stream by digging a series of earth banks across the direction of flow in the valley bottom above her plot. The banks, which were about 30 metre long and about 2 metres wide, slowed the floodwater down, giving it more time to infiltrate into the ground. This meant that there was an increase in soil moisture on her farm and the water level rose in the well she had dug in the centre of her plot. The well now provides clean drinking water for Agnes's family and neighbours as well as water for irrigating vegetables.

Like many other farmer innovators, Agnes Mughi is experimenting with a number of different approaches to enhance the productivity

Agnes Mughi's productive farm.

of her land. Her second innovation is a bio-pesticide made from dried chilli peppers, neem leaves and local aloe.

Agnes is a part-time social worker, and a role model for other local women. She has great strength of character and believes strongly in what she has to offer. In Mwingi district she has frequently been invited by Farmer Field Schools to explain her innovations to other farmers.

Rainwater harvesting

Peter Olochoki Letoya's first innovation came when he moved to a much drier area in East Mau. He realised that he needed to do something about the water shortage that was distressing his crops and threatening the livelihood of his family. Three years ago, he had the idea to collect rainwater runoff from his rooftop and store it in underground reservoirs. Since then, his reservoirs have been full. Today, it is clear that his idea has been a success but in the beginning he was afraid it would not work.

"When I first started to dig the holes for the reservoirs, I was hiding behind the house so that the neighbours would not see me. I did not want people to think I was crazy", he recalls.

Now that Peter Olochoki Letoya's rainwater harvesting technique has proved to be functional and efficient, his neighbours are no longer suspicious and some of them have started to adopt his method on their own farms. Working together with other farmers in the PFI-FFS project, Peter has been able to spread his ideas to other farmers and families outside of his community. He often gets visits from other farmers and farmers groups who want to learn how to harvest rainwater from rooftops. He has also benefited from visiting other innovative farmers and has been inspired by their ideas.

The tank that Peter Letoya invented is built underground by excavating soil and lining the sides of the pit with plastic sheets to avoid seepage. The top of the tank is covered with cedar posts. He chose cedar as a covering material because it does not rot easily and is not damaged by insects. Peter's tanks have attracted much attention in the area because in comparison with the common tank structures recommended by district engineers that are made out of concrete, they are very cheap to construct. *"My tank is about 10 percent of the price of the normal tanks found in this area"*, he says.

Peter Olochoke Letoya now has three underground rainwater reservoirs. These range in storage capacity from 1000 to 2500 litres. His family uses one for drinking water and the other two for watering trees and bushes on their land. At present he is thinking about collecting rainwater in an elevated tank so that he can start working with drip irrigation.

Another of his ingenious ideas is to use banana trees as nurseries for sugar canes. Peter discovered that the layers of spirally arranged, overlapping leaf bases in the stem of the banana tree form "pockets" that contain water. He placed some sugar cane cuttings in the pockets in the stem and these grew very quickly. In addition to the water from the banana tree, the improvised sugar cane "nursery" also receives moisture every morning from the dew that condenses on the banana leaves. Once they have grown roots, Peter plants the sugar cane cuttings in his fields.

Conclusions

Today, a significant proportion of poor people who depend directly upon the natural environment live in water scarce regions. All over the world, smallholders need water for their agriculture, livestock and households. Small-scale water solutions seem to be a key for enhancing food productivity for poor farmers and pastoralists in dry areas. Local innovators like Alex Ole-Pere, Agnes Mughi and Peter Olochoki Letoya can be found everywhere in Kenya and many other countries too. The challenge is to find ways of encouraging their inventiveness and originality so that their ideas can be developed and shared with other land users.

Peter Olochoki Letoya's rainwater harvesting system.
Photo: Åsa Forsman.

Findings from the PFI-FFS project show that there is a real possibility for bringing together external and indigenous sources of knowledge in agricultural extension activities. Initial results of the PFI-FFS programme suggest that farmers show a higher level of adoption when new technologies are introduced by fellow farmers rather than by extension workers and outsiders. East African farming conditions are very diverse and therefore require solutions appropriate to the local context. By capturing local innovations and promoting indigenous knowledge in extension and development activities, sustainable solutions can be found and scaled up.

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A full paper of on the PFI-FFS initiative is available at www.eseap.cipotato.org/upward

R2.7
ARTICLE 1

Photo: Mohamed Mechergui

Three-layer cropping system around Tunisian oases

Improved irrigation efficiencies in Tunesian oases

The experience reported in this paper underlines the importance of actual field knowledge when agencies plan to improve water use efficiencies in an irrigation system. A strictly technical solution is inadequate. Knowledge of the field situation provides insights into the real functioning of the system, actual water distribution and the importance of socioeconomic factors.

Mohamed Mechergui and Gerrit Van Vuren

Kebili, in the Tunisian Sahara, has a mean maximum temperature of 40ºC and minimum 5ºC. Annual rainfall is below 100 mm and wind speed is sometimes high and charged with dust. Formerly, irrigated agriculture was only practised near the natural water springs and the cropping system consisted of three layer, namely date palms, fruit trees and a ground crop. Today, irrigation has increased considerably and now covers an area of around 7,660 hectares spread around 68 oases.

Two distinct groundwater layers are in use: the so-called terminal complex and the continental intercalair aquifer. The former, which is most used is over-exploited in the Kebili region because there are a large number of illegal wells. In 1986, 680 of these illegal wells were pumping 2,700 l/s, over 40% of the total 6,200 l/s being extracted. A sustainable flow rate should not have exceed 4,500 l/s. The second aquifer is less intensively used: the rate in Kebili being 980 l/s and 650 l/s in Tozeur. This is because extraction requires a high technological input where wells are installed. Apart from these two aquifers, water can also be drawn from the shallow water table. Theoretically, the capacity of this shallow water table should be 4.8 million m^3/year but only 1.6 million m^3 is used because some of this water is saline.

Piezometer readings clearly show the degradation of the water sources with a drop in piezometric head of about one meter per year in both aquifers. The degradation of shallow ground water through salinisation is the result of high ground water levels. Observations show, for example, that the water table in Faouar oasis was 47 meter below soil surface in 1956; today it is at surface level. The rapid degradation of the different water sources show that the present agricultural oasis system is far from sustainable. In this article we will describe suggestions for improvement, with special emphasis on the oasis of Rahmat, which is fairly representative of the majority of traditional oases in the region.

The oasis of Rahmat

When it was created in 1932, Rahmat supplied a total irrigated area of 32 ha from two artesian wells. These were sufficient to irrigate a crop system of date palm, fruit trees and alfalfa. The area was subdivided in 0.25 ha individually owned plots.
Over the years the oasis has been extended to 92 ha and is equipped with two pumped wells operating 20 hours a day. The total discharge is 86 l/s and this water is collected in a concrete distribution box from which it is divided into three equal parts and lead through pipes to three sectors. Here there are a number of outlets each serving a block of about 3 ha. Water is brought to the surface into open canals that further distribute it to the farms. In each sector, the water delivery rotates over the blocks to create an irrigation interval of 14 days, with an irrigation length of 8 hours per ha and a discharge of about 30 l/s. Within the sector the irrigation is organised so that water delivery starts from the outlet at the top of each canal. On these sandy soils, surface irrigation is the only technique used.

The Association of Collective Interest (AIC), a farmers organisation, plays an important role in all but daily management. It fixes the water price with district authorities, gives directives on how water distribution should be organised and settles conflicts between farmers.

The day-to-day distribution of water is handled by an operator, who is responsible for opening and closing the outlets. The only guidance herefore is the time required per hectare (which is 8 hours) and the sequence of opening, normally from head to tail. Farmers know when they will get water, so they open the canal bund in the basin nearest the canal in advance.

An office-based solution

In the present irrigation approach, the depletion of water resources is clearly a major problem. Part of the water is pumped from non-renewable fossil water, the rest comes from an over-extraction of renewable ground water. At the same time, heavy leakage from the earth canals causes high groundwater levels in the oasis and leads to land salinisation. As a solution to this problem, engineers suggested replacing the open canals with 200 mm PVC pipes. Each farmer would get a riser pipe from which water can be taken. It was believed that this would prevent farmers using more water than they needed, depletion of the groundwater reserve would be reduced and ground water levels would be lowered.

Actual water management

Field observations revealed that water management is actually organised very differently. It became clear that the operators role is more important than is formally recognised. In practise he decides on the irrigation time for each owner depending on his estimation of plot size, his relation to the farmer and his social position.

It was observed that the three sectors, although equal in size, did not receive the same discharge. In one sector actual discharge was 25% higher than in the other two sectors under the pretext that its irrigated area was larger.

Inconsistencies also occurred at the outlets. Farmers take water from different outlets giving different excuses for doing so. Although irrigation timings appear to be respected, water is sometimes transferred to another farmer.

Another problem in the management of water was observed inside the irrigated area of one outlet. Contrary to the specifications of the project, which defines a standard plot as being 0.25 ha, actual areas vary from one palm tree to 2 ha. Each farm managed the water in its own way in the absence of a specific recommended method. Some farmers do not do any levelling inside the parcel which leads to considerable water loss. Whilst the required dose was 50 mm, we observed actual irrigation gifts varying from 100 to 300 mm and more. This was partly because farmers have no method of control. In one case we observed that the profile was wetted beyond a depth of two meters although the palm tree's active root-zone does not go below 120 cm.

Another observation is that the irrigation system is just supply based, in the sense that the quantity of pumped water does not depend on the quantity needed in the system. In summer this fixed supply is in good equilibrium with crop water requirements. In the winter season, however, the supply is several times higher than demand and causes a steep increase in groundwater level.

Water losses in the unlined, very sandy canals is high. We measured canal losses of 30 to 60 % over a length of 400 to 1000 meters.

Both cropping system and type of farmer was not what we expected. Instead of the three layer cropping system, we observed that date palm was the main crop. Only occasionally was there a second layer crop of apricots, fig or olives. There was generally no third layer crop except in those places where alfalfa, an important crop for those farmers raising goats, was cultivated. Many plots were owned by absentee farmers who lived in Kebili or even Tunis and who hired labour to cultivate their plots. There was also share cropping. Many of these 0.25 ha plots were not, in fact, being cultivated by farmer families.

A different strategy

On the basis of this field research it became clear that the problems surrounding water management in these oases were more complex than assumed. Apart from the problem of diminishing water resources, we found an extensive type of agriculture being practised in which only palm tree cultivation is important. Water management at farm level is poor and water distribution to farms is unequal. In this situation, the construction of a buried pipeline system up to field level would be insufficient to solve the problems of irrigation inefficiencies at field level, especially during the winter season; discrepancies between the designed and actual irrigated area; and inequity in water distribution.

To improve water use efficiencies, it is important that farmers should first be willing to re-establish the three layer crop system on which the irrigation system was first established. It is suggested that improvements that require little external input, improve the knowledge base of farmers and, which are oriented towards improving organisation, be introduced. The construction of a buried pipeline system would only then be possible. The advantage of this system would be that payment per unit of land could be changed into payment per volume of water supplied, an approach that certainly helps to increase water use efficiency. It might facilitate a demand-based irrigation system, where farmers have to apply for water in advance and create options for changing from present surface irrigation towards low pressure sprinkler or even drip system techniques.

This case of the oases in Tunisia touches on a common problem in irrigation development. Although irrigation agencies are generally well informed about regional water resources, they tend to work with a generalised (idealised) picture of the field situation in mind. Detailed field observations would provide them with a much better insight into how farmers handle water, and contribute to the development of more appropriate solutions. Often such an approach will focus more closely on the farmers' organisational structure and knowledge base. Sometimes, a bottom-up and participative approach can reduce the level of investments required for construction work and safeguard the use and management of the scheme because farmers feel involved in the analysis of the problems.

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Traditional water harvesting systems need to be improved

In the dry regions of south and centre Tunisia, with a long-term average rainfall of around 200 mm, water harvesting is the only way to secure crop production. The landscape consists of undulating hills and mountains denuded of natural vegetation. Soils are poor and extremely shallow and rocky. Most land is being used as marginal rangeland except for those places where runoff water and soil are being harvested which permits cultivation of olives and barley and sometimes even apples, apricots, chickpea, faba bean, lentiles or watermelons. Different traditional water harvesting systems can be found of which the *Jessour* systems is best known. This system consists of a series of stone and earth walls, called tabias, built across the stream beds of narrow valleys. The *tabias* collect and retain soil washed down hillsides by torrential rains, forming terraces in a stair-step fashion down the slope of the valley. This has worked for centuries, but recently the *jessours* have not been well maintained because of outmigration, shortage of labour and loss of skills and traditional knowledge. This is destroying the systems and is causing serious erosion.

The Institut des Regions Arides (IRA) in cooperation with the International Centre on Agricultural Research in Dryland Agriculture (ICARDA) are now trying to adapt these traditional systems to existing economic conditions. Farmers as well as scientist have made some innovations. For example farmers are using plastic bottles to irrigate young olive trees. The bottles (without bottom) are filled with pebbles and placed top down with the opening near the roots of the trees. In this way irrigation water is stored and gradually made available to the plants.

Scientists have designed new techniques to store and guide the precious water directly to the roots of the trees or crops to increase water efficiency. In a process of participatory technology development these techniques are now being adapted to the conditions in which the farmers work.

This programme is also part of the documentation of farmer innovations in soil and water conservation exercise referred to on page 21 of this issue.

Information on the programme: **Dr. B. Chahbani,** ARI, 4119 Medenine, Tunisia, Fax: +216 5640435.
Information on the *Jessour* system can be found in: **Les Tabias**. by Khlifa Alaya, Werner Viertmann and Thorsten Waibel. 1993. 192 pp. ISBN 9973-9735-0-X. GTZ, PO Box 5180, 2636 Eschborn 1, Germany.

R2.7
ARTICLE 2

Spate irrigation: Good for people, livestock and crops

Spate irrigation is an ancient form of water harvesting. It is a method of managing unpredictable and potentially destructive flash floods for crop and livestock production. By making water available, it can contribute to increasing the diversity of farming systems where it is found. It is the major source of livelihood for many communities in west Asia, the Middle East and Africa. Despite being the oldest type of irrigation, it is still the least studied, understood and documented.

Frank van Steenbergen and Abraham Haile Mehari

Spate irrigation water management systems are among the most spectacular and complicated social organisations around. While spate irrigation has the potential to contribute to poverty alleviation and food security, it is often neglected and forgotten in agricultural investment programmes. The area under this type of irrigation is more than 2.5 million hectares worldwide, with about 2.1 million households depending on spate irrigation systems. It is found in west Asia (Pakistan, Iran, Afghanistan), the Middle East (Yemen, Saudi Arabia), North Africa (Morocco, Algeria, Tunesia) and the Horn of Africa (Ethiopia, Eritrea, Sudan, Somalia) and more sporadically in other parts of Africa, South America and Central Asia. The largest area is in Pakistan and Iran. In the Horn of Africa spate irrigation is on the increase.

This water management system requires the local construction of bunds and canals that are able to withstand flash floods. They must be designed to gently guide large volumes of water over large areas, slowing down their erosive power. Soil bunds, as they are in use in Pakistan and Eritrea, can stretch over several kilometres. This requires much ingenuity in their construction. Factors which need to be considered include: the location, the angle to the river bed, the distance from the new diversion bund, the soil from which they are made, the compaction and use of (brushwood) reinforcements. The amount of collective work needed is huge. This requires strong local co-operation and agreement on how to distribute a common good that is uncertain and uneven. In many cases the number of people working on the common structures is so large that it is in the benefit of upstream farmers to give a fair deal to downstream land users. This is the only way to mobilise enough people to carry out the repair works.

Higher production, fewer chemicals

Spate irrigation systems sustain highly productive low input agricultural systems. One example is the Eastern Lowlands in Eritrea, where sorghum yields of 3750 kg/ha are often achieved. On occasion, yields reach 6000 kg/ha, thanks to a sophisticated system of moisture management. The secret is a refined system of water management – in which the land is ploughed prior to the irrigation season to "open up the soil". After the fields are watered they are carefully ploughed and mulched – and the sooner this takes place after irrigation, the more moisture is stored. In the Eastern Lowlands the command area is also kept relatively compact. Because of this, it is possible to have two or even three spates on the land, and to store sufficient moisture in the soil to last throughout the season.

In most spate irrigation schemes, farmers prefer to use local cultivars as they are well adapted to the local agro-climatic conditions. There is minimal use of chemical and organic fertilizers as most farmers believe that their soils are naturally fertilized by the fine sediments that are deposited during each irrigation. The use of pesticides and insecticides is also rare. High costs, limited availability and risk aversion are other factors that have limited the use of agro-chemicals. Most spate-irrigating farmers cannot take the risk of losing their entire crop in a dry year by changing to higher yielding varieties that are less tolerant to drought and require fertilizers and other agro-chemicals.

Zero-grazing

Livestock is an integral and important component of the livelihoods of the resident households in most spate-irrigated areas. Access to sufficient fodder is therefore crucial. The main

How it works

Spate irrigation is a type of water management that makes use of water from "spates", short duration floods. Spates – lasting from a few hours to a few days – are diverted from normally dry riverbeds and spread gently over agricultural land. After the land is inundated crops are sometimes sown immediately. Often the moisture is stored in the soil profile and used later. The spate irrigation systems support low economic value farming systems, usually cereals (sorghum, wheat, barley), oilseeds (mustard, castor, rapeseed), pulses (chickpea, clusterbean), but also cotton, cucurbits and even vegetables. Besides providing irrigation, spates recharge shallow groundwater (especially in river bed), they fill (cattle) ponds and they are used to spread water for pasture or forest land in some places.

Photo: Spate Irrigation Network

Simple infrastructure development can help people to manage flash floods and spread water over land – the working procedure of "spate irrigation".

source of fodder is crop residues and rainfed grazing lands. A second source is the cultivation of spate-irrigated fodder crops, such as (green) sorghum. In Eritrea and Sudan, ratooned sorghum is an important feed for livestock as well. Weeds cut from the fields and along the canals are another source of forage, as are leaves from trees in and around the spate-irrigated fields. For instance, households in the Sheeb area in Eritrea practice "zero-grazing" from October to May. In this system, the animals are fed with cut grass from the fields. This prevents livestock from causing damage to standing crops, and economises on the scarce animal feed. Farmers in the northern part of Amhara State (Ethiopia) also indicated that spate irrigation boosted the availability of animal feed due to a significant increase in biomass production. The improved availability of animal feed has improved household income generated from livestock products.

Spate irrigation systems generate important benefits. In the first place, obviously, spate irrigation makes it possible to grow crops in hot arid and semi-arid regions where evapotranspiration (the loss of water from soils and plants) greatly exceeds annual rainfall. In addition, spate irrigation systems may also have one or more of the following benefits for the households living in and around the command areas of these schemes: (improved) access to animal feed; recharge of groundwater aquifers; (improved) access to water for humans and livestock; and (improved) access to forest products.

Efforts to support spate irrigation farmers

In general, the provision of agricultural extension services to farmers in the usually remote spate-irrigated areas is poor, whereas any available services often do not meet the specific needs and demands of spate-irrigating farmers. The entire range of Green Revolution techniques, for instance, is not applicable.

For a long time, attention to spate irrigation has focused very much on civil works improvements. These have in many cases disturbed the balance and the sustainability of the system. Typically, an ingenious system of independent structures able to manage the high floods and high sediment loads, was replaced by a single concrete diversion structure. This was the pattern followed in the so-called modernisation era in Yemen and Pakistan. The net result has either been the rising of the command area, water rights conflicts (as a many independent systems were replaced with a single off-take) or interference with the subsurface flow feeding the local aquifers. Moreover, attention to improving the diversion of river water from such modernised systems was in retrospect uncalled for in some areas, as most water was diverted from the dry river beds anyhow and no water was left unused.

Many small things make magic

There are several ways of improving spate irrigation beyond focusing on diversion works only. This is best described as the magic of many small things. Promising activities include:

- Improving water productivity and soil moisture management. Field-to-field structures (inlets and overflow structures) can be improved, allowing more regulated inflows and outflows during the hectic times of spate irrigation. Another strategy is to ensure that animal traction power is adequate for ploughing and mulching, so as to conserve soil moisture after irrigation. A final strategy is to consider concentrating flows towards a relatively compact command area, so as to increase the probability of land being irrigated. This makes it less risky for farmers to prepare their land prior to irrigation. More compact command areas also increase the chances of a second and third irrigation, taking crops out of the "stress zone", as practised in Eritrea.
- Introducing new crops – vegetables, cucurbits, pulses, oilseeds. What is common and popular in one area often has not spread to the next area.
- Making more of wild crops. In most spate areas there is a large variety of wild vegetables, fodder plants and mushrooms (including truffles). Seeds of these are collected from a large catchment and dumped during the floods into the favourable moisture conditions of the spate systems.
- Investing in post-harvest technology, such as seed cleaning and improved storage, which in Pakistan for instance, reduced grain losses from 7% to zero.
- Enhancing the productivity of livestock. This would include improved access to animal feed, watering points and veterinary services, as well as the processing and marketing of livestock products.
- Promoting local agroforestry, particularly of indigenous trees that serve to stabilise surrounding areas and provide fuel and timber, medicinal products or bee forage. Sometimes this has to be accompanied by improvement in the governance of local forestry.
- Controlling invasive species. In spate irrigated areas in Sudan and Yemen, an invasive weed has blocked river beds and grown over canals. Innovative ways of reusing this weed (for charcoal for instance) could turn it into a resource.
- Improving drinking water facilities in the spate areas. These are often inadequate and unreliable, such as unprotected open ponds. A range of technical and institutional measures are available to improve drinking water supply.
- Developing complementary uses of groundwater and spate water, including promoting recharge with small structures and special water allocation rules. The combination of spate and groundwater can sustain production systems that are among the most productive anywhere.

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Sustainable plots had 20% to 40% more topsoil. Photo: World Neighbors

Measuring farmers agroecological resistance to hurricane Mitch

Eric Holt-Gimenez

In October of 1998, Hurricane Mitch, one of the Caribbean's five most powerful hurricanes of the twentieth century, slammed into **Central America** causing US$ 6.7 billion in damage to infrastructure and industry (primarily agriculture) an amount approximately equal to 13.3% of Central America's GNP. Two meters of rain in less than one week coupled with mudslides and landslides washed away crops, animals, buildings, roads and bridges. Topsoil, lost from hillside farms, silted rivers that overflowed their banks, flooding fields and urban areas. Over 10,000 people died and 3 million were displaced or left homeless. The environmental damages were incalculable. The countries hardest hit were Honduras, Nicaragua and Guatemala. All areas affected by Hurricane Mitch are characterised by an uneasy mix of large-scale plantation agriculture and extensive cattle ranching (primarily for export) alongside small, very poor, subsistence farms. The hillsides and fringes of the large holdings are surrounded by mosaics of hundreds of thousands of poor rural families who eke out an existence by farming basic grains on ecologically fragile land and by engaging in a myriad of other seasonal, part-time, informal rural and urban work. Most observers agree that the unprecedented magnitude of the disaster is the consequence of decades of deforestation, non-sustainable agricultural practices and other forms of environmental degradation that left the region exceptionally vulnerable to an erosive event.

'Sustainable' farms suffered less

While first reports regarding agricultural damage simply indicated that the levels of destruction were massive, subsequent on-site observations began to reveal a more subtle, differentiated pattern. Farms using what are commonly understood to be 'sustainable' practices appeared to have suffered less damage than their 'conventional' neighbours. These farms belonged to smallholders working within a multi-institutional, regional movement for sustainable agriculture (agroecology or LEISA) known in Central America as Campesino a Campesino (Farmer to Farmer). The farming practices commonly encountered in Campesino a Campesino included a wide range of soil conservation and sustainable cultivation methods, tested and promoted by smallholders for nearly thirty years. Most common amongst them were soil and water conservation methods, reduced or discontinued use of chemical inputs, cover crops, agroforestry, in-row tillage, organic fertiliser and pesticides, and different forms of Integrated Pest Management.

An opportunity to compare impact

In general, these sustainable farms exist as islands and archipelagos within a greater, conventional 'sea'. While often localised and geographically fragmented, they provided an excellent opportunity to compare the agroecological resistance to the hurricane of sustainable farms to that of conventional farms. The presence of Campesino a Campesino, made up of farmers and technicians experienced in farm experimentation and farmer to farmer training, also provided the opportunity to carry out an extensive, participatory, action research project in the low, medium and high impact areas of Hurricane Mitch. Several researchers with years of experience working in the Campesino a Campesino Movement designed a study and wrote a proposal. World Neighbors, an NGO working in the region, agreed to sponsor the project, helped to find funding (Ford, Summit, Rockefeller and Inter-American Foundations), and provided administrative support.

Much interest in the study

From February through May of 1999, 40 different NGOs with sustainable agricultural research and development (SARD) projects trained and mobilised 100 farmer-technician teams and 1,743 farmers to carry out paired observations of specific agroecological indicators on 1,804 neighbouring, sustainable and conventional farms. The study spanned 360 communities and 24 departments in Nicaragua, Honduras and Guatemala. The primary objectives of participating in the study were threefold: First, farmer-promoters and NGOs in the Campesino a Campesino Movement were eager to compare their farms to conventional farms because demonstrating a higher level of agroecological resistance would imply a higher level of sustainability. After years of being told that sustainable agriculture was not 'viable', nor 'economical', they were anxious to dispel doubts about the importance and effectiveness of their practices. Secondly, NGOs were very interested in evaluating the effectiveness of years of support for farmer to farmer SARD. Commonly, these projects are evaluated on the level of implementation (number of workshops, participants, terraces, compost heaps, etc.) However, the study gave them an opportunity to evaluate the level of their agroecological impact. Finally, all participants were interested in influencing the agenda for agricultural reconstruction after the hurricane. If farmers could show that sustainable farms were more resistant than conventional farms, then a strong argument could be made for a participatory, sustainable agricultural reconstruction strategy.

A collaborative action

An intensive period of organising, training, data collection and field monitoring began in February of 1999. It was crucial that field data be collected before the onset of the rainy season in late April. Each team had one technician and two farmer-promoters. They carried out observations on the ten best examples of sustainable farms and on the ten neighbouring, conventional farms. Paired observations had to be located in close proximity, in the same position and cardinal orientation in the watershed, have the same general slope and similar environmental surroundings (fields, trees, infrastructure, etc.).

Agroecological indicators included topsoil depth, rill and gully erosion, percent vegetation, crop losses and structural damage. Each team member specialised in specific steps and measurements of the field procedure to reduce and standardise observational errors. The owners of both farms in the paired observations accompanied the team on both sustainable and conventional plots, then signed off on the field sheet indicating measurements and observations had been free of bias. Technicians interviewed farmers regarding their observations of the hurricane, the damage patterns, and the different reasons for any agroecosystem failures. National research coordinators in each country held periodic sessions with teams for feedback, troubleshooting and the correction of field errors.

Significant differences

Field data from the farmer-technician teams was entered into an interactive ACCESS database for each country. Initial results (averages) were processed for distribution among participants. While there was some local variation, the overall results indicated an overwhelming trend of higher agroecological resistance on the sustainable farms. Sustainable plots had 20% to 40% more topsoil, greater soil moisture, less erosion and experienced lower economic losses than their conventional neighbours. Statistical tests showed that some of these differences were highly significant (there was only a 0.0001 probability that these differences were due to chance) and most were acceptably significant (0.02 to 0.05).

Conventional farmers convinced

Fifteen different workshops were held in the countryside to share the results of the field research with participants and key local and municipal actors. Farmers, promoters, technicians and project coordinators collectively analysed the results and gave feedback. Sustainable farms had fewer and smaller gullies and areas of rill erosion. All of these indicators were seen as contributing to both productivity, and to the conservation of the watershed. Further, because of crop diversification, sustainable farms averaged lower economic losses, and in Nicaragua even showed profits, despite the hurricane. However, when correlated to steep slopes (>50%), high storm intensity and other extreme environmental factors, some of the differences between sustainable and conventional farms 'collapsed', indicating that these techniques have thresholds of effectiveness. Finally, the participants themselves indicated what could be the most impressive result of all: over 90% of conventional farmers participating in the study indicated a desire to adopt their neighbours' sustainable practices.

A learning process

Participants enthusiastically claimed that the study had been a highly successful learning experience, and one that had established new bonds of trust between farmers, promoters and technicians. For most farmers, it was their first experience with research, and for others, the first time results of on-farm research had been returned and shared with them.The study also revealed that, at the local level, many organisations and farmer groups had mobilised themselves already in response to the humanitarian emergency situation. Farmer to farmer groups helped to motivate self-help efforts in their communities, rather than simply waiting for outside assistance. This capacity for self-mobilisation among farmer groups indicates that resilience has a social as well as a technical dimension.

Vetiver Grass for disaster mitigation

Last year, around Christmas and New Year thousands of Venezuelans had a miserable time just trying to survive the floods that have ravaged their communities and homes. Although we do not know the details of all the causes behind the flooding and mud slides, we know that when vegetation is removed and the soils become fragile, even moderate rainfall conditions can bring about a calamity.

Vetiver Grass Technology (VGT), if used to stabilise agricultural land, peri-urban building areas, deforested hillsides, riverbanks, levees, and highway embankments, could help to reduce the damage that might occur from future high rainfall in Venezuela. The Vetiver Grass Network strongly urges policy makers and relief agencies to consider VGT as an important tool for rehabilitation and to provide jobs for thousands of unemployed people.

VGT has proven very effective in the Far East for protection against cyclones, just as in El Salvador and Honduras, where it provided near perfect protection against the ravages of Hurricane Mitch in 1998. Some of these stories have been documented and can be found at: http://www.vetiver.org . The website also contains reports from other parts of the world, and information on practical guides such as:

- Training manual of the international training course on the vetiver system. Hard copies of the training manual are available from The Royal Projects Development Board. To obtain a copy email your name and address to Suwanna Pasiri. <pasiri@mail.rdpb.go.th>
- Vetiver grass - a hedge against erosion. The Vetiver Network (TVN) has published a revised (fourth) edition of this book - commonly called the Green Book. Copies available from TVN.

Dick Grimshaw, TVN, 15 Wirt Street NW, Leesburg, Virginia 20176 USA.
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What's needed for scaling up of SARD?

With the aid of drawings, clay models and skits prepared by the participants, farmers then described how their fields and villages should look in three, five and ten years hence if agricultural reconstruction was implemented using farmer to farmer, SARD techniques. Then, farmers analysed the obstacles to the scaling up and scaling out of SARD, and suggested projects and policy ideas for participatory, sustainable agricultural recovery. In general, technology and training methodologies were not seen as limiting to SARD. After all, farmer experimentation, cross visits and farmer to farmer training are the pillars of the Campesino a Campesino Movement. However, it was strongly felt that national credit, market, agrarian and research policies favoured Green Revolution technologies rather than SARD. Although NGOs had been instrumental in establishing SARD alternatives, if SARD was to scale out nationally, and scale up institutionally, proactive national policies were required to push it beyond the NGOs local 'micro-project' sphere of influence.

Sharing of results

Findings from these workshops were synthesised and presented by the participants at national meetings in the capital cities of Honduras, Guatemala and Nicaragua. Key actors in government, relief, development and research institutions were invited. Farmers and technicians presented their findings; the national research coordinators, the methodologist and the principal investigator gave their reports. In-country researchers in agricultural economics and disaster prevention gave topical presentations. Notable figures such as Nobel Prize winner Rigoberta Menchu, several government ministers, and representatives from the United Nations gave keynote addresses. A video of the research project (see below) was shown and distributed.

Potential of SARD demonstrated

The Campesino a Campesino Movement in Central America has demonstrated the social, environmental and agricultural advantages not only of SARD, but also of farmer-led approaches to sustainable agriculture. The study itself demonstrates the tremendous potential for research and development within farmers' movements. While farmer-promoters within the Campesino a Campesino Movement have carried out on-farm experiments and have shared their knowledge across borders for thirty years, this was the first time ever that farmers had collaborated on a regional research project. Participants have expressed their desire to establish national and regional farmer research networks to continue their agroecological research.

Limited impact on national policies

A year after the study, the participating organisations from Nicaragua met to assess the impact of their research. Most organisations reported widespread adoption of agroecological practices at the project level by conventional farmers who had participated in the study or had heard of the findings. A number of NGOs had successfully used the study to persuade international funding institutions to support their efforts at sustainable reconstruction. Some participants were members of territorial committees and used the study to argue for sustainable reconstruction at the municipal level. One organisation gave a workshop on sustainable, participatory reconstruction to donors in Europe, and used the study as an example of the human capabilities in Central America.

This trend of local and territorial impact appears to have been repeated in Honduras and Guatemala. Unfortunately, the study does not seem to have had much of an impact on national reconstruction policy in any of the three countries. While there is evidence of receptivity to the sustainable approach by the government of Honduras, Mitch seems to have been forgotten in Guatemala. Official Nicaraguan reconstruction efforts have been plagued with political difficulties, with the government focusing on large-scale infrastructure projects designed to support tourism and conventional agricultural exports rather than sustainable agriculture. Efforts by NGO networks to influence national policy have not met with much success, with or without the study.

Public pressure needed

The Mitch study has uncovered a conspicuous 'policy ceiling' in sustainable agricultural development. While NGOs and the Campesino a Campesino Movement have been instrumental in developing the technical and methodological aspects of sustainable agriculture in Central America, they are limited in their ability to influence the *policy context*. Lack of a favourable policy context, and the lack of political will on the part of national governments to create one, appears to be holding back grassroots efforts at scaling up sustainable agriculture. The next task confronting sustainable agricultural development may be to translate farmer-to-farmer successes on the ground into the broad-based, public pressure needed to influence national policy-makers.

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For more information

- World Neighbors. 2000. **Reasons for resiliency: toward a sustainable recovery after Hurricane Mitch**, and accompanying video, **Changing course: recovery & research after Hurricane Mitch**. Both can be ordered on-line through the World Neighbors' web site (http://www.wn.org); by sending an e-mail to order@wn.org; or by writing, calling or faxing World Neighbors, 4127 NW 122nd Street, Oklahoma City, OK 73120 USA; phone: +1 405 752-9700; fax: +1 405 752-9393. See also page 30.

Participants enthusiastically claimed that the study had been a highly successful learning experience. Photo: World Neighbors

Water harvesting: community-led natural resource management

R2.8
ARTICLE 2
R2.11

Anil Agarwal and Sunita Narain

India is in water crisis despite its relatively high average rainfall. Water harvesting can offer a solution. If 5-10% of the land were used for rainwater collection there would be enough water for irrigation and household needs. Recent initiatives, both at community and government level, have made use of long-neglected water harvesting traditions. The results show that reviving water harvesting systems stimulate rural development and restores local ecosystems. This article discusses some of these initiatives and explores how community-led natural resource management can be facilitated.

Photo: S. Rajam / CSE

Tanks (eris) once watered one-third of the irrigated land in Tamil Nadu.

Water crisis

Forty percent of the world's population currently experience serious water shortage. India is one of the 80 countries bearing the heavy social, political, economic and environmental costs of this crisis. Water quality problems affect some 44 million people in the subcontinent and there is widespread pollution. Fluoride, arsenic and iron have entered the groundwater and seawater pollutes groundwater aquifers. In the summer when the situation is particularly acute, women and young girls have to walk long distances to fetch water. Wells are dug deeper and deeper lowering the groundwater table still further and gradually wells dry out. Fifty years ago there was twice as much water available per capita as there is today.

Water is not only vital for human survival, it is also essential for sustainable biomass-based economy. Although India has made substantial investments in an effort to exploit river and groundwater resources to service large-scale irrigation systems and urban water supplies, these systems have rarely reached the rural poor. Often large-scale water developments have led to inefficient and inequitable distribution of water resources and to forced re-settlement.

Decline of water harvesting

There are water-harvesting traditions in many parts of the (developing) world. India's traditional water-harvesting structures are treasures of ingenuity. Over the centuries, people in different types of ecosystems throughout India have used basic engineering skills to develop a wide variety of techniques to meet their water needs. Today, when the art and science of 'collecting water where it falls' is needed to help ensure an adequate, sustainable and equitable distribution of fresh water, it has become a dying wisdom. Serious efforts must to be made to combine water-harvesting traditions with the insights of modern science and technology (Agarwal and Narain, 1997).

Decades of British rule ravaged the peoples' water knowledge heritage. The consequence of British determination to maximise its exploitation of India's riches resulted in impoverished rural communities and the destruction of their resource management systems. Water management structures were also seriously disrupted.

Photo: Ganesh Pangare / CSE

In Konkan region water flows from one farm pond to the other during rainy season.

Technological changes such as the introduction of tubewells put richer farmers in command of the tank area. Those who could afford to install these wells no longer have an interest in cooperating with the rest of the community in managing the tanks. Many central and southern Indian cities like Hyderabad, Chennai (Madras) and Bangalore grew up around traditional water harvesting systems. In the urban areas these systems have either disappeared because of pressure from real estate lobbies or have become heavily polluted. Today, traditional water harvesting systems are only important in remote areas such as the Himalayan states which are beyond the immediate reach of water bureaucracies.

Learning from experience

During the 1980s, several successful community-based resource management ventures emerged in response to the water management crises. Some of these are described below. They show the policies needed to turn ecological poverty into sustainable economic wealth. Today, these initiatives are particularly important because they have now matured. An advanced level of ecological succession has been reached and their economic impact is clearly visible.

Sukhomajri village

Sukhomajri, near the city of Chandigarh, is the first village in India to have income tax levied on earnings from the ecological regeneration of its degraded watershed. In 1979, when the nation was facing a severe drought, the villagers built small tanks to capture rainwater. They agreed to protect their watershed to ensure the tanks did not get silted up. The forest department's assurance that they would have the right to use forestland and its grass was a major incentive. The villagers had argued that they should benefit from the biomass


Photo: Ganesh Pangare / CSE

A bihar (rectangular catchment basin with embankments on three sides) still used by farmers in Bihar.

produced in return for protecting the watershed. The state forest department agreed to give the villagers these rights if they paid the forest department a royalty equivalent to the average income it had earned before the villagers started watershed protection.

The combination of public, private and community investments and the participatory efforts of the villagers have resulted in a rate of return of 19% according to one cost-benefit analysis. The tanks have resulted in a threefold increase in crop production. The amount of grass and tree fodder available to cattle in the protected forest has increased considerably and as a result more milk is being produced. As prosperity increases, Sukhomajri's economy has also changed. "Who could imagine that televisions, tractors and bicycles could be had for mere grass and water?" asks one of the villagers.

One of the most impressive results of the project is that the cost of desilting Lake Sukhna, which supplies water to downstream Chandigarh, has fallen dramatically. The inflow of sediment has been reduced by more than 90% saving the government Rs7.65 million ($0.2 million) each year in dredging and other costs (Chopra et al., 1990).

Ralegan Siddhi village

Ralegan Siddhi is a village in a drought-prone area of Maharashtra. The annual rainfall is between 450 mm and 650 mm. Villagers could never confidently rely on a regular harvest. In 1975, the village was poverty stricken and there was less than half a hectare of irrigated land per family. Krishna Bhaurao Hazare, a retired driver from the Indian army, began constructing storage ponds, reservoirs and gully plugs. Due to the steady percolation of water, the groundwater table began to rise. Simultaneously, government social forestry schemes were used to plant 300,000-400,000 trees in and around the village. Because of the increased availability of irrigation water, fallow land was brought under cultivation. The total area under production increased from 630 to 950 hectares and average yields of millets, sorghum and onion increased substantially.

The village made every effort to ensure equitable access to the resources generated. Water is being distributed equitably and only crops with a low-water consumption are grown. Today nobody in the village is dependent on drought relief. Incomes have increased substantially and income distribution is more even than in other parts of rural Maharashtra.

Ralegan put more emphasis on participatory democracy than representative democracy. The village created an impressive system of decision making and some 14 committees ensured that people participated in all decisions. A *Gram Sabha*, a participative democratic institution, was established to take community decisions and ensure that each household was involved in the development process. It was also able to exercise social pressure when necessary. (Mahapatra,1997).

A dead river back to life

Rainwater harvesting has brought the River Arvari in dry and drought-prone Rajastan back to life. (see Shree Padre p14). The river flows through a drought stricken region - villagers living on the margins of survival are desperately poor and find sustenance by migrating to cities to look for work. According to historical records of the region, the river Arvari used to provide groundwater recharge to wells in the area. But nobody can remember seeing it flow except during the short monsoon period. The river – in its 45km journey to its confluence in the reservoir of a dam on the River Sainthal – flows through about 70 villages. Its source lies in the degraded hills near the village of Bhaonta-Koylala.

In 1986, working with a local NGO, the Tarun Bharat Sangh (TBS), the villagers of Bhaonta-Koylala built a rain-water harvesting structure or *Johad* to trap the rainwater and use it to recharge the groundwater. Since then many more water harvesting structures have been built in the Arvani catchment. These small dams have helped to recharge the river and since 1995 it has been perennial.

Jhabua District

Transformation of rural ecosystems with people's participation, such as the cases described above, has remained isolated and scattered, and usually led by remarkable NGO leaders. Governement efforts in afforestation and watershed management have rarely been able to reproduce these successes. The problem is often that the devolution of power to local communities has been half-hearted and inadequate. People's participation has remained largely stuck in the 'you participate in my programme' mode.

In Madhya Pradesh, however, the government's watershed management programme (the Rajiv Gandhi Watershed Development Mission) has become an outstanding example of government interventions promoting public participation in environmental management. The statewide programme was initiated by the chief minister Digvijay Singh who was inspired by Krishna Bhaurao Hazare's work in Ralegan Siddhi. The programme is integrated and participatory in its approach. Today trees are flourishing in a district that 15 years ago looked like a moonscape and wells are literally overflowing with water in a place that was described as chronically drought-prone (Agarwal and Mahapatra, 1999)

The programme created several tiers of institutions: policy coordination at state level; implementation and coordination at the district and macro-watershed level, and work at village level to ensure that all villagers are involved in the effort. Some 1748 women's groups, for example, have been created in 374 villages in Jhabua and together they have 25,506 participants. Most important, however, serious efforts have been made to give local communities power over decision making and control over resources. Villagers play an active role in the management of watershed programme funds. Nearly 80% of the programme's funds are put in a bank account managed by Watershed Development Committees made up of village people. The Watershed Development Committee brings together the important interest groups in the village in a way similar to the *Gram Sabha*.

Eco-restoration is possible

These case studies show clearly that eco-restoration is possible even in highly degraded lands and that it can regenerate local rural economies and alleviate poverty in a sustainable and cost-effective way (Agarwal and Narain, 1999). In other words, helping the people to help themselves by improving their local natural resource base is a viable and effective strategy for poverty alleviation. The key to eco-restoration lies in good management and use of the local rainwater. This must be supported by community decision-making systems and institutions. There must also be legal and financial structures to enable and promote community action.

Examples such as those referred to above remain scattered because the governance system needed to foster people's control over natural resources does not exist. Locally-led instances have emerged despite and not because of the system. Effecting change at the micro-level requires enormous perseverance and effort on the part of an individual initiator especially if the governance system does not empower local communities to improve and care for their resource base. However, the government of Madhya Pradesh has now shown that the state can reproduce community-based efforts if there is adequate political will and pressure on the technical and administrative bureaucracy to deliver. The transformation of Jhabua is a fine example of the results that can be expected when a government seriously starts working with people.

Conclusions

The potential of water harvesting is enormous. The cases mentioned here show that improvements begin with increases in the quality and productivity of croplands as available water increases. This leads to better grass production from the local grasslands and slowly increased production of fodder and timber resources from tree and forestlands.

But for water harvesting to support sustainable rural development, there will have to be a change in the governance of water systems (Box 1). Decentralized systems of water management are needed. These in turn demand a community-based system of natural resource management. The only way this objective can be achieved is by deepening systems of participatory democracy and expanding people's participation at village-level. Every settlement must have a clearly and legally defined environment to protect, care for and use. It must also have an open forum in which all can get together to discuss problems and work to common solutions. By strengthening and emphasising the importance of open forums, common solutions and common natural resources, the developing world can make a determined bid to revive dying community spirit and to rebuild its devastated environment.

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Anil Agarwal and Sunita Narain, Centre for Science and Environment, 41 Tuglakabad Institutional Area, New Delhi 110 061, India. Fax: +91-11-6980870; Email: sunita@cseindia.org ; http://www.cseindia.org (eg with information on *Down to Earth*, water harvesting, community forestry and biodiversity).

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Box 1. Steps towards a community-based system of natural resource management

- *Maintain water as a community resource.* Water as a common property resource is the crucial link for improving the productivity of private croplands. It is vital to maintain the use of local water as a community resource and not allow water distribution to follow the inequity in land holdings.
- *Adopt an integrated approach to village resource development.* Current rural development efforts are extremely fragmented, focusing mostly on agriculture, and often efforts are contradictory and counter-productive. Yet the 'village ecosystem' usually consists of several integrated components: crop lands, grazing lands, forest and trees, local water bodies, livestock and various energy sources. What happens in one component invariably impacts on the others, and all is maintained in a delicate ecological balance. Thus development must focus on the holistic enrichment of the ecosystem, whereby attempts are made to increase the productivity of all components, from grazing and forestlands to croplands, water systems and animals.
- *Ensure people's participation in the regeneration of village assets.* All new plantations and grasslands have to be protected, but this will need the support of the people. Without this support the survival rates for village assets like check dams and tanks will be poor.
- *Strengthen village institutions to enable people's participation.* Rational use and maintenance of village land and water resources requires discipline. Villagers have to ensure that animals do not graze in their protected commons and that local water body catchments are conserved and properly used. They must also ensure that the common produce from these lands is equitably distributed within the village. Villagers can only achieve this if there is an effective village-level institution to give them an impetus and involve them in controlling and managing their environment. Deepening democracy at the grassroots is critical in the process of ecological regeneration and local water management. The village-level institution must work with a high order of democracy and transparency in decision-making in order to engender cooperation and discipline within the group members. In India, village-level institutions have worked best when they are built along the lines of the Gandhian concept of a *Gram Sabha*, a village institution that empowers the adults of the village to take decisions.
- *Promote decision-making forums.* Open public forums are more transparent and accountable and promote more confidence in community decision-making than small, elected village councils. Resolution of intra-village conflicts and coordination are invariably easier in open village forums where equitable community decisions can be taken than when organisations are closed and secretive.
- *Develop a legal framework that supports local rights to manage resources.* The Indian government owns a substantial portion of the land and water resources. As a result village communities are often alienated from their management or protection. This can lead to massive denudation of forests, overexploitation of grazing lands and neglect of local water systems. Laws dealing with natural resources like land, water and forests will have to be changed to give people the right to improve and develop the village natural resource base. The legal framework should encourage people to take the initiative to develop their natural resource base without waiting for government to act first.
- *Channel government funds directly to village institutions.* In the present system, various functionaries and agencies of the government control the finances upon which village development depends. Ultimately, only a small proportion reaches the community and it is often spent on projects over which the village has little control and which are not local priorities.

R2.9
ARTICLE 1

Access denied: the Brazilian land issue

Luc Vankrunkelsven

From the time the Portuguese established themselves in Brazil in the sixteenth century, the country has been ruled by an economic elite whose power lies in land. A major piece of legislation enacted in 1850 - the *Lei da Terra* - recognises two forms of land use in Brazil: *propriedade* (possession) and *posse* (right of use or usufruct).

Lei da Terra defined land in capitalistic terms as a commodity to be bought and sold, making it possible for a small minority to establish control over the countryside. As a result, when slavery was abolished and impoverished immigrants started to enter the country in the late nineteenth century, most of them could only claim users' rights to land. Known as *posseiros* or "farmers without papers" their heirs still depend on usufructory rights granted by private and company landlords.

Green counter revolution

Demand for fair land redistribution has increased steadily in Brazil in recent decades. However, the military dictatorship (1964-1985) and the United States wanted no "communist-type" land reform. Instead they encouraged the Green Revolution - a counter revolutionary answer to the cry for justice. Super seeds, pesticides and large subsidies were made available and resulted in a new gold – soya. But family farms drawn into soya monoculture were unable to compete with the large estates. *Posseiros,* without papers and rights were driven from their farms and joined the hundreds of thousands of farm labourers who, having lost their jobs because of mechanisation, joined the massive exodus to the cities.

Churches and resistance

During the military dictatorship the churches were the only places where people could organise and many civil society movements emerged from the grassroots of the Christian community. Amongst these was the trade union CUT (*Central Unica dos trabalhadores)* and the PT (*Partido dos trabalhadores)* - both established by the present socialist President of Brazil Luiz Inácio Lula da Silva – as well as the *Comissao Pastrol da Terra* (CPT), *Movimento dos Trabalhadores Rurais sem Terra* (MST), women's organisations and human rights groups. The CPT, CUT and MST were particularly important actors in agricultural politics.

The organisations involved in land issues such as the CPT, CUT and MST support each others efforts. CPT is a service of the Catholic Church. It helps farmers and farm labourers as well as the urban poor and their organisations in their struggle to hold on to or acquire land. In some of the provinces where the MST is less strong CPT organises land occupations.

The trade union CUT works with farmers, farm labourers and urban labourers. Since 2002, several alliances such as *Federação dos Trabalhadores da Agricultura Familiar da Região Sul* (*Fetraf-sul/CUT)* have been formed. CUT has established a number of cooperatives on *assentamentos* (redivided land), particularly in *Mato Grosso do Sol,* the north and the north-east.

One of the organisations most specialised in the fight against unfair concentrations of land is the MST. MST has a strong international reputation and this status is reflected in its website which is available in six languages. Since the late 1990s, MST has broadened its perspective to include agroecological issues.

Land reform through the market

In 1998, then-president Fernando Henrique Cardoso launched "land reform through the market". With financial support from the World Bank, local banks provided money to farmers so they could buy land from estate owners. Farmers, in fact, were paying for the land reform which was their right and richly compensating estate owners at the same time. The effect of Cardoso's programme on small farmers was disastrous: land prices rose and many went bankrupt, unable to pay back their loans. Even so, in this way, 80 000 farmers gained access to land. Cardoso's approach raised considerable discussion in Brazil and within the landless movement. Lack of credit eventually put an end to this neo-liberal approach to the land problem.

Lula and land reform

Since January 2003, when President Lula came to power, there has been more hope of a strong land redistribution policy. Lula is closely associated with the fight for land reforms. One of the priorities of his government is the *Zero Hunger Programme* in which the family agricultural model has been given a central place. The question for all those concerned with the politics of land reform in Brazil is whether "Lula" will be able to stay out of the landowners "clutches".

For its part the landless movement currently follows a double strategy: it puts government under pressure by encouraging land occupation yet it is also ready to engage in dialogue. On 2 July 2003, the President met several representatives of MST. These amicable discussions were not greeted with enthusiasm by the country's estate owners.

Future direction

The land issue continues to be a life or death struggle. In the first 6 months of 2003 alone, 31 farmers have been murdered. Whilst the landless movement demands that a national plan for land reform be drawn up which would ensure one million farm families will receive land rights by 2006 and an immediate solution is found to the problem of the 120 000 farm families living in camps, landowners are organising themselves to hold on to their (il)legal possessions. In this highly volatile situation it is difficult to predict the direction land reform will take in Brazil.

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A full version of this article is available from ILEIA.

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Improved fallows and local institutions

Olu Ajayi and Roza Katanga

Low soil fertility is one of the greatest biophysical constraints to increasing agricultural productivity and food security in many Sub-Saharan African countries. The use of supplementary inorganic fertilizers has become less affordable for many farmers in countries such as Zambia, following the removal of subsidies on these inputs. In response, the use of improved fallows, also known as fertilizer tree fallows, has been developed by the World Agroforestry Centre (ICRAF) in eastern Zambia over the last ten years, as a sustainable way for small scale farmers to restore soil fertility (see also LEISA Magazine Vol.17, No. 3, October 2001). This technology involves planting nitrogen-fixing, fast-growing trees that produce easily decomposable biomass, and improve soil physical conditions.

Photo: Olu Ajayi

Zambian Members of Parliament discuss agroforestry with farmers.

Given the profitability of fertilizer tree fallows and the positive impact of the technology on households and the environment, efforts are being made to scale up the adoption of the technology. These efforts have been hindered by existing practices such as the regular use of bush fires and free-grazing by livestock during the dry season, among other reasons. The absence of private property rights over land means that livestock are allowed to graze freely in the fields during the dry season. Often, these animals are owned by wealthier farmers. The livestock usually deposit their dung in the *kraals* of their respective owners rather than in the fields where they have grazed, so poorer farmers do not gain from the grazing. The livestock destroy trees by browsing the leaves or physically trampling over the plants. This has been a major discouragement to tree-planting and the widespread adoption of fertilizer tree fallows. These problems are not restricted to fertilizer tree fallows alone but also affect other sustainable practices for soil fertility management like conservation farming, because the maize stover is often grazed by free-ranging animals or destroyed by fire.

Respecting customary institutions

ICRAF, in collaboration with the Ministry of Agriculture and Cooperatives, World Vision International and other NGOs promoting agroforestry technologies in Zambia, joined forces to form the Consultative Workshop on Agroforestry. In 1996, two meetings were held to share information on the state of improved fallows among partners and discuss approaches through which local communities could be involved in enabling the adoption of the technology. During these meetings, the threats posed by fires and uncontrolled grazing practices were highlighted and discussions focused on what could be done to reduce the threats. One suggestion made was to involve the customary chiefs who have traditionally used their authority to ensure social conformity in the area. Although the powers of the traditional authorities have changed compared to the pre-independence era, chiefs are still much respected and do hold sufficient powers to enact by-laws and appropriate sanctions through the traditional hierarchy of leadership. Two major traditional authorities were identified in eastern Zambia, being the matrilineal system for the *Chewa* ethnic group and patrilineal system practiced by the *Angonis*. In each of the two systems, the highest level of authority is the paramount chief. Below him – this function is always held by a man – are the senior chiefs, each of whom is in charge of a group of chiefs. Next in rank to the chiefs are the headmen, who are individually responsible for the welfare and administration of a single village. Chiefs, senior chiefs and paramount chiefs hold and preside over court sessions related to issues concerning the traditional affairs and people within their respective domains. They are assisted by a council called *indunas,* made up of selected representatives of the various communities under the jurisdiction of a chief. The *indunas* serve as advisers to the chief on administrative matters and are the spokespersons of the chiefs in their respective communities.

This local administrative setup was considered to be a good entry point for policy interventions regarding fire and uncontrolled grazing. The two paramount chiefs and their senior chiefs were approached, with the aim of showing them the existing and potential benefits of agroforestry. Such efforts included open forums for exchange of ideas as well as field tours during which the chiefs could observe the performance of maize, the staple food in the region, under improved fallow, and discuss with local farmers about their experiences with this technology. The result of the series of meetings, coupled with what the chiefs saw and heard regarding the performance of fertilizer tree fallows, was that in 1997 new rules were created by the chiefs for their respective ethnic groups. This was done in consultation with the *indunas* who were also responsible for informing their communities, chiefs and village headmen about the provision of the new rules. The by-law on grazing requires livestock owners to herd their animals during the dry season to minimize damage to other farmers' fields. The by-law on the use of fire prohibits indiscriminate setting of bush on fire during the dry season to avoid accidental or deliberate burning of trees and maize stover in fellow farmers' fields.

Impact of by-laws

An evaluation carried out in 2001/2002 showed that five years after the introduction of the new by-laws, there is a reduction in the two constraints mentioned above, particularly in problems associated with free grazing. The evaluation highlighted three issues: the need for increased awareness about the by-laws; taking the economic interests of a broader range of stake-holders, particularly livestock owners, into consideration in the implementation of the by-laws; and continued policy dialogue with the chiefs to provide feedback on how the by-laws are working. Farmers who practice improved fallows are very pleased with the by-laws, but livestock owners regard the by-law on grazing to be unfavourable because it restricts the animals and requires extra labour for herding the animals during the dry season. An immediate reaction to the findings has been to increase the range of fodder producing tree species in the improved fallows, so that the competition for feed by livestock during the dry season is reduced. These trees could also ensure that economic interests of livestock owners are well taken care of; this is very important because they often influence the implementation and effectiveness of the by-laws on the ground through their wealth and social status.

In addition to the evaluation, policy dialogues were held in the communities, to achieve a consensus on the implementation of the by-laws and to enhance adoption of improved fallows. Various stakeholders participated, including traditional chiefs, village headmen, research and development organizations, farmers who practice improved fallow and those who do not, teachers and area councillors. Highlights of the evaluation were shared during four village policy dialogues and a provincial level policy dialogue in the years 2002 and 2003, and ways to deal with the problem of livestock browsing and fire were agreed upon (see Box). Some of the actions suggested by village communities have been carried out, as well as some actions requiring external assistance. Formal documentation of the by-laws is still a challenge because the high level of illiteracy among farmers may make it difficult for many of them to read the documents themselves.

Initiatives identified during policy dialogues to minimize fire and grazing

Actions that should be carried out by the village communities themselves

- Regular meetings to be convened by the headmen for group discussions
- Convene regular group discussions involving local community, tree-planting farmers and non-planters through the headmen to monitor agreements reached during the policy dialogues
- Embark on farmer-to-farmer visits in each village to share ideas
- Agroforestry farmers to make fire breaks in their fields
- All farmers to educate their children about the dangers of fires
- Livestock farmers to start animal herding for those who have not yet been doing so
- Initiate committees comprising agroforestry and livestock farmers to monitor progress on the implementation of the bylaws

Actions requiring assistance from outside the farm communities

- Government backing of the by-laws through a formal enactment
- Government should work closely with schools so that the pupils learn about the dangers of fire and the importance of agroforestry to the community
- Government and local leaders should sensitize and teach the people through mass media about the bylaws
- By-laws should be formally documented, issued by the chiefs and distributed to village headmen
- Agricultural institutions to provide appropriate fodder plants to livestock farmers
- Encourage farmer study tours to see how livestock and trees co-habit in other areas
- Publicize the by-laws through radio and other mass media

Lessons learnt

Several lessons have been learnt during the development and implementation of by-laws, including that:

- an existing traditional structure can serve as an entry point for policy intervention;
- collaborative efforts of several partners, such as technology developers, NGOs interested in promoting sustainable agriculture practices and government agricultural organizations, ensured that issues on agroforestry came from multiple voices and helped to strengthen the case for the by-laws;
- continuous review of how the new by-laws function is important, as is the willingness to modify them when required;
- there should be a readiness to build consensus (as far as possible) among different stakeholders within the community that is affected by the by-laws.

These experiences show that existing local policy and institutional arrangements will affect the adoption rate of a technology. The distribution of the benefits (or costs) associated with the technology will vary amongst the various social groups within communities. The evaluation study and related experiences demonstrate the importance of policy dialogues among stakeholders and how the development of appropriate local institutions has the potential to be combined with formal national policies to enhance the adoption of improved fallows and other soil fertility management options in Zambia. ■

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Getting farmers to adopt new technologies to address soil erosion and fertility problems is not easy. In Vietnam, a multidisciplinary research project to improve soil management in traditional mountainous agricultural farming systems managed to attract farmers' interest and stop soil erosion. This success stems from encouraging farmers, extensionists and researchers to jointly define and implement the project. Their different aims could be followed simultaneously: scientific results for researchers, better agricultural practice for extension workers, and economic success and free choice for farmers.

R2.10
ARTICLE 1

Different interests, common concerns and shared benefits

Didier Orange, Tran Duc Toan, Paulo Salgado, Nguyen Duy Phuong, Nguyen Van Thiet, Clement Floriane and Le Hoa Binh

Soil erosion comes about because of both human activity, such as erosive farming practices, and biophysical factors, including intense rainfalls and sloping land. In Vietnam, the rising population level has encouraged agricultural production to shift from the rich-soil lowlands to the degradation-prone marginal uplands. In this context of severe agricultural intensification, soil erosion has become a major economic and environmental problem. It has affected the livelihoods of smallholders and has hindered the long-term development of these areas.

Many different organisations have responded to this problem by working on the development and promotion of better soil management practices, aiming at higher yields and reduction of rural poverty. Studies show that the promotion of a new practice as a major factor towards change, needs to be complemented by other factors, such as access to external markets and achieving higher incomes. In addition, policies and regulations have proved to have a further positive impact on the adoption of a given technique. This article examines a multidisciplinary research project on adoption of soil management techniques in three villages in Hoa Binh province, northern Vietnam.

Multi-institutional context

This work was part of an international research programme called MSEC (Management of Soil Erosion Consortium). Its objectives are to promote sustainable land management systems, evaluate the biophysical, environmental and socio-economic effects of soil erosion, and to generate reliable information for the improvement of local policies and regulations, in the uplands of Southeast Asia. After a four year assessment, working with around 50 small scale farmers in the commune of Tien Xuan (approximately 50 km west of the capital Hanoi), this programme found that local factors can be far more important than national policies in determining change. These results provided the basis for an integrated crop-livestock project carried out by the Vietnamese Soils and Fertilizers Research Institute (SFRI) in Vietnam and Laos, in collaboration with the National Institute of Animal Husbandry (NIAH) in Vietnam and the National Agriculture and Forestry Research Institute (NAFRI) in Laos. In addition, two international research centres were involved, IRD (French Institute of Research for Development) and CIRAD (French Agricultural Research Centre for International Development). The crop-livestock project's aim was to support farmers in their efforts to reduce poverty and enhance environmental sustainability in mountainous areas. This was to be achieved by promoting new technologies that build on existing knowledge and farming practices.

Finding the right mix of activities

The research focused on the integration of animal husbandry into the traditional agricultural farming systems in the region, which are based on cassava production and forestry in the uplands, and rice cultivation in the lowlands. A discussion process between farmers, local decision-makers and scientists helped define the activities, to ensure all their goals would be met. In Vietnam, improved management of soil fertility in rice- and cassava-based systems, and simultaneously cultivating fodder grass on steep slopes matched both the farmers' and scientists' interests. The plan was to produce sufficient animal feed during the cold winter season and the warm rainy season, while at the same time decreasing soil erosion. The project's activities, which began in 2005, included:

- testing fodder species for sloping lands on experimental plots and demonstration sites, considering temperate grasses and legumes (such as *Avena strigosa* or *Medicago sativa*) and also tropical species (*Panicum maximum*, *Brachiaria* sp., *Paspalum atratum* or *Stylosanthes* sp.). The main purpose was to secure the production of cattle feed, (especially in winter), and also to select the best species for soil conservation during the rainy season;
- setting up demonstration sites, focused on soil and nutrient management when growing cassava (on upland plots) and paddy rice (in the lowland areas). The aim was to show how well balanced fertility management can improve crop yields without increasing the use of external inputs.

Joint decision-making

The activities in each village and the process used for each trial and demonstration site were jointly defined by farmers, extension workers and researchers. Their involvement in the planning phase helped farmers and extensionists to clearly understand the project's framework and their responsibilities in the implementation of trials and demonstration sites. All activities were meant to promote new technologies offsetting erosion, and at the same time build local capacities. The two-

Soil sampling on a fodder field in the Que Vay village. Mr. Thiet, an agronomist working for SFRI, had the help of many interested farmers.

pronged strategy that emerged included field visits to take measurements on erosion and soil fertility, complemented by more than 20 Farmer Field School sessions, and regular meetings between extension workers and researchers.

One main interest was to consider local initiatives. As scientists, we found it necessary to complete our knowledge and understanding of the farmers' decision-making processes, as a first step to ensure their involvement. It was thus interesting to see how their participation resulted in new activities coming up. For example, the fodder crops were initially proposed to be cultivated on sloping land, resulting in animal feed in the winter (the farmers' main concern) and also in an efficient way of protecting the soil (the researchers' interest). However, as the lowlands are often left fallow during the winter, some farmers started testing temperate fodder crops like *Avena* on their paddy fields. All of them had very positive results in terms of crop yields, and it was relatively easy to feed their animals. After one year, around 80 percent of all lowland farmers were growing *Avena* and other temperate fodder crops through the winter.

When the project was initiated in 2004, the MSEC team worked on planting fodder on sloping land with only five smallholders in one village (Dong Cao). Within three months, these farmers bought cows using their own resources. The next year, the People's Committee of Tien Xuan Commune became officially involved. Most smallholders in the area also became very interested in integrating animal husbandry and reforestation activities into their farming systems. In 2006 and 2007, the production of fodder crops in this area was rapidly adopted by more than 300 farmers, from seven different villages and three communes. The impact in terms of erosion was immediate: all measurements showed that the trees and the fodder crops stopped soil losses.

Factors behind successful farmer involvement

Looking back at the project, we can see why farmers became actively involved and worked together with other stakeholders. Two major factors stand out: first, that farmer leaders (such as the People's Committee) were involved in the project from the beginning; and second, that scientists were forced to adapt their experiments to the farmers' demands. Another important aspect is the participatory approach that was followed, in which farmers, local extension workers and researchers worked together in the diagnosis of the problems, in setting up the pilot demonstration sites, and in disseminating and scaling up results. This also proved to give a valuable opportunity to scientists to conduct on-farm experiments on scientific processes such as surface runoff and the soil organic carbon cycle, leading to new insights that helped their dialogue with farmers. Evidently, a participatory approach also meant following different aims or interests simultaneously: scientific results for researchers, the appropriation of better agricultural practice for extension officers, and economic success and free choice for farmers.

Among the factors for success in this case, we can identify the following:

- facilitating local participation in the research and extension processes aimed at improving the economic efficiency of the area's farming systems;
- consulting and informing local stakeholders (farmers and village representatives) on all key steps of the experiment;
- making it possible for farmers to assess the productivity and the nutritional value of different fodder species, as well as their seed production capacity; and
- developing training workshops for the dissemination of new technologies (fodder production, husbandry integration, fertilizer management) at farm level, especially when conducted by local extension workers.

It must further be noted that a desire to reduce soil erosion was not the driving force that led to the adoption of these techniques. According to the farmers involved, what motivated them most was that their incomes were improved when adopting new forestry and fodder production practices.

Learning from this new collaborative approach

The crop-livestock project demonstrated that sustainable agricultural practices require a judicious combination of incentives and the promotion of technologies that have a significant impact on smallholder incomes and on environmental sustainability. It has also demonstrated that although farmers are concerned about the environment and resource management, this in itself may not motivate them enough to adopt sustainable land and water management practices. By increasing farmers' incomes through intensive livestock production, this project has shown that indirect methods can help control erosion.

In addition, the project effectively contributed to improving local extension approaches, as well as creating better links between researchers, extensionists and farmers. The participation of the local population ensured that local interests and local knowledge in the development of new farming techniques were met. The collaborative approach between researchers and farmers has supported spontaneous innovations within the local farming systems, resulting in a better integration of their different components.

The project's greatest limitation has been its short duration (two years). Nevertheless, it was enough time to build farmers' capacities in integrated natural resource management. This was also possible due to the co-operation of all stakeholders (including policy makers) throughout, in spite of their having different immediate interests.

This process should continue to be developed. For example, different "payment for environmental services" schemes could be considered, whereby downstream farmers agree to support upland farmers through mutual arrangements, all of them framed within an economic contract.

■

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Subsidised fertilizer:

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ARTICLE 2

In Malawi, the fifth poorest country in the world, the government introduced a voucher programme for small scale farmers, providing them access to subsidised fertilizer and seed. The country suddenly saw bumper harvests in both 2006 and 2007. Are fertilizer subsidies the way out of poverty for small scale farmers in Africa?

"Fertilizer vouchers are key to the empowerment of African farmers"

Eric McGaw, head of communications at the Alliance for a Green Revolution in Africa (AGRA).

If you're after social inclusion, you can't do better than provide farmers with fertilizer, at least in sub-Saharan Africa. This region has long been characterised by poor soils – soils that continue to deteriorate as their nutrients are mined year after year. Leaving their lands fallow is not an option for farmers. Their choice is stark: either they plant or wind up begging for food.

But many farmers cannot afford fertilizers and improved seeds. The key to changing this is to improve farmers' access and purchasing power through a targeted income transfer system. Recently, the Alliance for a Green Revolution in Africa (AGRA) has been working with various partners to facilitate access to fertilizer and seeds by developing networks of rural agro-dealers that bring these farm inputs closer to farmers, while lowering costs. Also needed are more effective ways of providing support to poor farmers who cannot afford costly inputs. Vouchers are therefore offered to them that can be used at their local agro-dealer shop, expanding both options and affordability, while building private markets.

It's working

AGRA targets the poorest farmers in Africa, and the voucher system is specifically suited to their needs. This system has already worked wonders in many African countries with seeds. Likewise, farmers, who would be excluded from access to fertilizer in any scheme involving cash, are directly benefited by the voucher system.

Our last topic, "How effective are Effective Micro-organisms", received valuable responses on our website. In our digital newsletter, E-LEISA, this discussion is summarised for you. To subscribe to this newsletter,

The agro-dealer programme was first developed by the Rockefeller Foundation in Malawi in 2004 and AGRA has been building on this. Triggered by massive government support to provide subsidies for seeds and fertilizers, Malawi, a small land-locked country, went from being an annual recipient of food aid to a net exporter of maize within two years, bringing desperately needed income to the cash-strapped country. Not only that, but Malawi actually became a food donor to other countries in Africa. Similar voucher programmes have been extended to poor farmers in Kenya and Tanzania.

Two lessons from these national efforts are clear. One: the voucher system provides farmers with additional purchasing power to acquire seeds and fertilizer. Two: building agro-dealer networks makes it possible for farmers to obtain these inputs at their doorsteps.

Private sector partnership

The need for a consolidated approach for fertilizer procurement in Africa is especially urgent now because of the rapidly increasing prices of fertilizers on the global market and the tightening of fertilizer supply. The price for a tonne of DAP rose from US$ 245 in January 2007 to about US$ 1300 in mid 2008, excluding shipping and inland distribution costs to the farm gate. Many African countries are experiencing great difficulties in securing access to fertilizers and high costs have put additional pressure on government budgets. Accessing finances for importing fertilizer is also increasingly challenging because of the high prices and the need for higher levels of collateral on loans. Unless immediate measures are taken to tackle fertilizer procurement and assure lower-cost supplies, the food crisis will worsen. To this end, AGRA will work closely with the African Development Bank, the New Partnership for African Development (NEPAD), multilateral partners, the private sector and commercial banks to develop solutions to fertilizer procurement.

Investments

Clearly, the current fertilizer supply and pricing situation on the global market and impacts on African countries must be reviewed. Additional investments in infrastructure will be required to support bulk procurement systems. These investments entail a high level of commitment from both the fertilizer industry and the countries with access ports.

Above all, a comprehensive fertilizer policy framework must be developed that will ensure that fertilizer reaches farmers. This framework needs to include the development of downstream fertilizer distribution systems as well as safeguards to ensure efficient and environmentally sound use of fertilizers. We at AGRA believe that the voucher system, when coupled with rapid development of rural agro-dealer networks and targeted public subsidies, is the best way for farmers to increase their food production and secure their food security.

AGRA is a platform that emerged in 2006, to develop programmes that boost farm productivity and incomes for the poor, while safeguarding the environment. Contact: Alliance for a Green Revolution in Africa (AGRA), P.O. Box 66773, Westlands 00800, Nairobi, Kenya. E-mail: emcgaw@agra-alliance.org ; www.agra-alliance.org.

Two views

"Fertilizer subsidies are a mirage for solving hunger"

Rachel Bezner Kerr, assistant professor at University of Western Ontario (Canada), works with the Soils, Food and Healthy Communities (SFHC) Project in Northern Malawi.

Over the past year Malawi's fertilizer subsidy programme has been highlighted as a "success story" for improving food security and agricultural productivity for smallholder farmers. Fertilizer subsidies, which were made available to 1.8 million households in 2007, reduced the market price of this volatile commodity by about two-thirds. Many experts point to the government of Malawi's decision to export maize this year, and the high estimates of production as evidence of reduced hunger. International news articles trumpeted that Malawi had "ended famine" by ignoring the advice of the World Bank and the IMF, in providing subsidies to farmers.

Price increases

However, simply exporting food does not mean that hunger has ended in Malawi. In fact, it is the large scale farmers who exported a surplus. In northern Malawi many families experienced food shortages this year. Families who didn't produce enough maize from their own farms had to rely on purchased maize, which increased dramatically in price this year, in keeping with global trends. Current prices are 126-139 percent above the five year average. Many poorer farmers with low food supplies resorted to harvesting their maize early in order to compensate for this price rise. The high crop production predicted in late 2007 was overestimated, and late distribution of fertilizer was one reason for lower than anticipated yields. The Famine Early Warning Systems network predicted that food access will deteriorate for the poor in the coming months.
The financial cost for fertilizer has skyrocketed in the last year, following rising fossil fuel prices. The United States Department of Agriculture indicates that costs for fertilizer have increased by 65 percent from 2007 to 2008.

Even with a timely arrival of fertilizers, simply increasing yields does not translate into a decrease in hunger for poor farming families. Beyond the household, poor farming families in Malawi face a host of problems that cause or worsen hunger, including high medical costs, rising prices and low incomes.

Voucher politics

Farmers in Northern Malawi note that many families only received one coupon for 50 kg of fertilizer, which was not enough to produce adequate yields. Some farmers pointed out that the distribution within villages often marginalised poorer families, privileging those with ties to local leadership. "I got one coupon this year, which is not enough for my maize production." said Rodgers Msachi, community leader and farmer in Ekwendeni region. He added "You should not mix politics with someone's life. Even if you get a coupon, it may only be this year. Next year, a new president might say I won't give you fertilizer but flour."
Stockard Nyirenda, head of the farmer research team leading the SFHC project, explains: "Fertilizer on its own doesn't add fertility in the soil. Food for the soil is residues, manure. The farmers themselves know that if they apply fertilizer this year, they get high yields, but next year there may not be any fertilizer and yields will be down. Indeed, depending on fertilizer subsidies means relying on the vagaries of politics and the market for your food.

Legumes more sustainable

Over the past eight years, farmers involved in the SFHC project have taken a different road to improving their food security. They grow different legume intercrops like pigeonpea and peanut, and incorporate crop residues into their soils, growing maize the following year and saving legume seeds in community seed banks. This agroecological approach addresses both soil fertility and dietary diversity, with peanuts, pigeonpeas and soyabean. Between 2000 and 2008, 5000 farmers in over 100 villages received legume seeds and training on these intercrop systems. While judicious use of subsidised fertilizer may contribute to improving food security in the short term, the medium and long term costs of this option will be paid by poor farmers in Africa. Fertilizer is a highly carbon-intensive nutrient source. Reliance on fertilizer rather than organic material degrades the soil and increases carbon emissions, harming marginalised farmers the most. Creating dependencies on commodities like fertilizer through subsidies exposes national governments to increased risk from price volatility and availability – this risk is necessarily passed on to farmers.

In Malawi since 2000, the SFHC project (www.soilandfood.org) joins Canadian and Malawian researchers focusing on agroecological strategies to improve farmer productivity and health. Contact: Soils, Food and Healthy Communities Project, Ekwendeni Hospital, PO Box 19, Ekwendeni, Malawi.

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PHOTO 14

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