Natural Resource Management

Basic concepts and strategies

Draft D5 NOT FOR CIRCULATION

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MEAS aims at promoting and assisting in the modernization of rural extension and advisory services worldwide through various outputs and services. The services benefit a wide audience of users, including developing country policymakers and technical specialists, development practitioners from NGOs, other donors, and consultants, and USAID staff and projects.

Catholic Relief Services (CRS) serves the poor and disadvantaged overseas. CRS provides emergency relief in the wake of natural and man-made disasters and promotes the subsequent recovery of communities through integrated development interventions, without regard to race, creed or nationality. CRS' programs and resources respond to the U.S. Bishops' call to live in solidarity – as one human family – across borders, over oceans, and through differences in language, culture and economic condition. CRS provided co-financing for this publication.

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Contents

List of figures **5**

Acknowledgements **6**

Foreword **7**

Preface **8**

Introduction **10**

Lesson 1. Why are natural resources important? **13**

Quiz 1. Why are natural resources important? 14
Field exercise 1: Natural resources are managed together 15

Lesson 2. The water cycle **17**

Quiz 2. The water cycle 22
Quiz 2. The water cycle 22
Field exercise 2. Viewing soil erosion in runoff water 24

Lesson 3. Managing water **26**

Quiz 3. Managing water 28
Field exercise 3. The importance of soil cover 29

Lesson 4. Watersheds and watershed management **30**

Quiz 4. Watersheds and watershed management 36
Field exercise 4. Seek out a problem area in your local watershed 37

Lesson 5. Soil composition **38**

Quiz 5. Soil composition 42
Field exercise 5: Measuring soil animals 44
Field exercise 6: Measuring topsoil depth 46
Field exercise 7: Determining soil texture 48

Lesson 6. Soil fertility, soil nutrients and nutrient cycles **50**

Quiz 6. Soil fertility, soil nutrients and nutrient cycles 54
Field exercise 8: Using fertilizers 55

Lesson 7. Plant health **56**

Quiz 7. Plant health 59
Field exercise 9: Local plant health 60

Lesson 8. Life systems in nature (ecosystems) **61**

Quiz 8. Life systems in nature (ecosystems) 65
Field exercise 10: Introduction to food webs 66

Lesson 9. Sustainable use – bringing it all together 68

Quiz 9. Sustainable use – bringing it all together 74
Field exercise 11: Ecosystem services 75
Field exercise 12: Protecting natural resources – today and for the centuries ahead 77

Annex 1. Answers to quizzes 79

Figures

Figure 1. Guide to soil texture by feel 49
Figure 2. Two scenarios for the future 78

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Foreword

In the community of San Francisco in Matagalpa, Nicaragua, the savings and lending group "Road to Success" used traditional and new approaches to natural resource management to build stable livelihoods. In two short years, with the help of their savings this group of 15 women developed a business for producing and selling vegetable seedlings – tomato, green bell peppers and cucumbers. Their success did not come easily. They had to rely on help from local NGOs and producer groups to get started, and had to learn multiple skills. Today, they plant on slopes with live barriers to help trap topsoil, prevent runoff and replace trees felled in previous years. They continued their good practice of minimum tillage – the members did not have draft animals. On advice from the local NGO, they no longer burn before planting, leaving plant residue as organic matter to enrich the soil. Finally, they constructed a simple gravity-fed drip irrigation system to save water, enabling them to produce for the market year-round.

By combining lessons from traditional farming practice with new skills, "Road to Success" was able to develop effective approaches to managing their natural resources. This is a new way of combating poverty in vulnerable rural communities – by building farmers' capacity in five types of skills:

- **Organizational management:** how to get organized to plan and manage their work.
- **Financial skills:** how to save money, invest in the enterprise, and maintain financial records.
- **Market and enterprise skills:** how to produce something that customers want to buy; how to find those customers; and how to plan their business so that it makes a profit.
- **Natural resources:** how to conserve their soil, water and other natural resources so they can produce on a sustainable basis.
- **Innovation:** how to find new, more efficient and more profitable ways of doing things.

In common with many other development agencies, CRS is incorporating market – and business – oriented approaches into its development efforts. We realize that increasing food production alone cannot move poor rural people permanently out of poverty. Building the capacity of smallholders to engage in profitable enterprises has therefore become an integral part of our agricultural development strategy.

Field agents, extension workers, and development managers typically focus on one particular area of expertise. This series of training modules gives them a broader understanding and the skills needed to help local people work together, manage their money and understand how to develop a sustainable and profitable agroenterprise.

Through building the capacity of local people, we are reshaping the way we support vulnerable communities. As in the case of "Road to Success," communities can become agents of their own development. They can identify and grasp opportunities that turn previous desperation into a brighter hope for the future.

Carolyn Woo

President and CEO, CRS

Preface

This set of manuals covers five skill sets for preparing smallholder farmers to successfully engage with markets and is an integrated and sequential approach to building vulnerable farmers' capacity for linking with markets. The manuals have been prepared for use by development facilitators, field extension agents and community leaders working with poor rural communities. The aim is to improve the livelihoods of these communities through better production and marketing of their crops and livestock products.

Each manual contains the following parts:

- **Lessons** provide the knowledge and skills you need to master in order to teach the 5-skills manuals to rural communities.
- **Quizzes** to test your own knowledge.
- **Field exercises** for you to use in helping farmers master the knowledge and skills they need. These exercises are printed in shaded pages and typically include a set of instructions. The field exercises are also available as a PDF document on the CRS website www.crsprogramquality.org/agriculture. You can print out this document and have the pages laminated so it lasts longer.

How to use this manual

As a learner. Read through this manual lesson by lesson, section by section, and absorb the information presented. At the same time, imagine the situations that you encounter in your work, and picture how you would use this information and techniques to help you work with farmers on improving their management of natural resources. Imagine how you would use the exercises. At the end of each lesson, answer the short quizzes. If you get all the answers right, congratulations! Go on to the next lesson. If you did not get all the answers right, go back and review that section again before moving on to the next lesson.

As a trainer working with field agents. You can use this manual to teach other field agents about natural resource management. You can present the information in the text, then work through the field exercises with the participants. If you use the field exercises with field agents, ask them to pretend that they are farmers.

As a field agent working with farmers and other rural people. Once you have taken this course and passed the quizzes, you will have gained useful knowledge on natural resource management that you can share with farmer groups.

You can use the information and exercises in this manual to plan how to work with farmers to increase their productivity while preserving and improving their natural resources. Every farmer group and every situation is different, so this manual does not try to tell you exactly what to. Instead, choose those items that you think the farmers need and can benefit from, and use this manual as a basis for building your own series of learning events so you can pass this information on to farmers. Feel free to **adapt** the field exercises and quizzes to suit your own situation, and to **develop new materials** as needed.

Wherever possible, you should work in a **participatory manner** with the farmers. This means you should make sure that it is not you but the farmers who are gathering and analyzing

information, and making decisions that will affect them. Your role is to facilitate their learning, not to do the job for them.

As a reference source. You can also use this manual as a reference. If you need to check on a technique or concept, look it up in the appropriate section of the manual.

Learning online

If you are a CRS staff member or partner, you can also study the ideas in this manual online, through an e-course. Contact your CRS supervisor for a **username** and **password**, then visit https://crs.brainhoney.com to register and start an online course. In some cases these courses may be available on a thumb drive, or smart stick.

The e-courses use the same text, quizzes and exercises as in this manual. Many of the tables are presented as **forms** that you can fill in online to help you record and analyze the data you have collected.

Farmbook software

CRS and partners have developed a software application called **Farmbook**, which you can download from the CRS website. You can use Farmbook to register a farmer group and collect information about their production and business performance. Planned features for Farmbook will allow you to do the following:

1. Register a farmer group;
2. Do a profitability analysis for a single product for your farmer group;
3. Write a business plan;
4. Develop a production plan for the season;
5. Keep a record of training events and asset transfers to a group;
6. Undertake a baseline survey and follow up annual audits.

To learn more about Farmbook, visit www.crsprogramquality.org/agriculture/Farmbook.php.

Introduction

Farmers directly depend on natural resources for securing their livelihood. Their crops grow in the soil. Water keeps their crops and animals alive. The nutrients in the soil feed their crops so that they can grow and thrive. Those farmers who primarily grow crops depend on good soil and water conservation measures for a good harvest. Others who primarily provide for their families by selling products from trees depend on sustainable forest management. Farmers who live in very arid areas may depend on irrigation to maintain longer growing seasons.

Farmers have much experience in growing crops and taking care of their animals; however, they often lack formal training in new or improved farming practices. They may not have had the time and the opportunity to systematically examine their farming practices and its impact on the environment. This manual aims to help you, **the field agent**, to support farmer groups as they learn about water, soil, plants, and ecosystems. You will play a key role in helping them develop natural resource management strategies so that farmers can build and maintain their livelihoods.

As a field agent working in agroenterprises, you will need to develop a range of skills in the following key areas:

- Group management
- Finance
- Marketing
- Natural resources management (this manual, and the companion manual on "Managing natural resources: participatory methods for designing and implementing NRM programs")
- Innovation.

These five sets of skills are covered in separate manuals in this series. The farmers you work with also need to acquire these skills. One of your tasks is to help the farmers learn and practice these skills so they can improve their livelihoods. The manual "Introduction to the five skills sets" will guide you on how to plan and implement a training curriculum on these skills.

Purposes of this manual

This manual aims to do two things:

1) To help you learn about **key concepts and strategies related to the management of natural resources,** such as water, soil, plants and ecosystems;
2) To help you **to teach these skills** to the farmer groups that you work with.

What type of farmers are we targeting?

The concepts outlined here are useful for all types of projects and groups. You might be working with agroenterprise or marketing groups interested in improving their productivity through better natural resource management. You might be working with Savings and Internal Lending Communities (SILC) or Rotating Savings and Credit Association (ROSCAs), which would like to take their savings and invest in a common enterprise or the marketing of a product (for example, woven baskets). You might be working with producer group that seek to maximize their crop yields in a degraded area. All of these kinds of groups can benefit from better

managing natural resources. This manual aims to reach smallholder farmers who have access to basic or minimal resources. The concepts and exercises are designed to be simple and user-friendly. You will most likely adapt these materials to your local context.

After learning about natural resource management...

At the end of this course, farmers will have a **better understanding of the basic science** behind key natural resources: how water moves across and under the land; how nutrients cycle through nature; why the soil's organic content is important and how to increase it; why different types of plants and animals are necessary to maintain a healthy environment as well as other important aspects. Thus, farmers will be able to **identify key concepts related to water, soil, plant, and ecosystem health.** Also, they will be able to **better manage these resources in their local environment**. The accompanying manual, "Managing natural resources: participatory methods for designing and implementing NRM programs," helps farmers create natural resource management plans based on these concepts.

Natural resource management is always useful – regardless if you are looking at a plot, a whole farm, or an entire landscape.

What is in this manual

This manual is comprised of nine lessons:

1. **Why are natural resources important?** This lesson introduces the concepts of natural resources and their management.
2. **The water cycle**. This first lesson on water looks at how water moves across and through the land. It covers excessive water flows (that cause flooding or landslides) and the lack of sufficient water (drought).
3. **Managing water**. Expanding on the introduction to the water cycle, this lesson provides tools how to better manage rainfall. It also gives more detailed information on managing excess water as well as improving absorption and conservation of water.
4. **Watersheds and watershed management.** The final lesson on water takes a broader look at the entire watershed. It discusses erosion and how to combat it. Also, techniques for identifying problem spots in watersheds as well as upstream vs. downstream considerations are covered.
5. **Soil composition**. Healthy soils are essential for maintaining and improving plant productivity. This lesson provides an overview of the different types of soil and their main characteristics. Also it covers key aspects of maintaining soil health, such as nutrient and soil organic matter management.
6. **Soil fertility, soil nutrients, and nutrient cycles.** Plants need nutrients to survive. In this lesson you'll learn about plant nutrient needs, and organic or commercial fertilizers that can support those needs. The lesson closes by taking a closer look at the application of commercial fertilizer.
7. **Plant health.** In addition to the main nutrients covered in the previous lessons, plants also need other nutrients to thrive. This lesson will also cover favorable air, water and soil conditions, and touch on the dangers posed by pests and diseases.

8. **Life systems in nature (ecosystems).** Organisms rely on each other, and each is necessary for the others to thrive. This lesson examines vital ways in which organisms interact with each other in their ecosystems, emphasizing the need to maintain balance.
9. **Sustainable use – bringing it all together**. This final lesson describes good practices for farming and managing of our natural environment, including land use planning and how to consider ecosystem services. It emphasizes that maintaining natural resources is crucial for securing the livelihoods of future generations.

These lessons can be transferred during a series of training workshops, or you might conduct some of these activities as you work with farmer groups to develop natural resource management plans, as described in "Managing natural resources: participatory methods for designing and implementing NRM programs."

Lesson 1. Why are natural resources important?

In this lesson you will learn:

- What is a natural resource.
- Why natural resources are important.

What is a natural resource?

A natural resource is any asset that we can obtain from our environment: water, soil, plants, wind, animals, minerals, the energy of the sun and many others. Natural resources are often seen in terms of economic value, because so many of them are crucial for people's livelihoods. People are also an integral part – unbreakably linked to our environment. Without water, air, soil, and minerals we would not be alive. A distinction is often made between renewable and non-renewable natural resources.

- A **renewable natural resource** is one that can regrow, or whose supplies can be replenished through natural processes. Some examples of renewable resource include plants, animals, insects, or wind. But being renewable does not mean that these resources automatically last forever. If the renewable resources in a particular area are overexploited for a long period of time, it is entirely possible that they may become endangered or even disappear altogether.
- A **non-renewable natural resource** is one that can be used up, one that will not replenish itself. Examples of these include oil, coal, minerals, or rocks. The use of these resources should be carefully monitored and managed according to their availability. The effects that their exploitation has on all the other resources and the environment as a whole should be carefully followed.

Managing natural resources

We need to be very aware of how we use the natural resources in our environment. We should use resources in a way that does not dangerously reduce their supply and we should preserve the balance between the different resources and organism in the environment.

- **Maintaining healthy ecosystems**. All living and non-living things interact with each other and co-exist in a balance. Disturbing this balance by overexploiting natural resources usually has broad effects on everything in the entire ecosystem. We are not immune to these effects. To live long and healthy lives we must work hard to maintain this balance.
- **Building sustainable livelihoods**. Farmers rely on the entire ecosystem (water, soil, nutrients, plants, animals and everything else in it) for their livelihood. How successful they are in providing for their families largely depends on how well they manage these resources. Sustainable livelihoods are good management practices that help farmers safeguard the environments while securing sufficient food and income for the entire family.

Quiz 1. Why are natural resources important?

See Annex 1 for answers.

1. **What is a "natural resource"?**
   a. Anything we can see around us
   b. Plastic and any other thing made from natural materials
   c. Any naturally occurring asset that is not man-made (like air, water, soil, trees, animals, birds, etc.)
   d. Assets that are unique to our environment (the specific cars, jobs, plants, animals etc.)

2. **Which sentence best describes the difference between "renewable" and "non-renewable" resources?**
   a. A renewable resource is anything that people can use over and over again (like a metal plate); on the other hand, a non-renewable resource is something that has to be thrown away once it has been used one time (e.g., cell phone scratch-card).
   b. A renewable resource is something in nature that "renews" itself (for example, trees can be reseeded after the parent tree has died); on the other hand, a non-renewable resource is one that cannot be replaced once it has been removed (e.g., gold in a specific gold mine).

3. **What are "sustainable livelihoods"?**
   a. Activities where people make a lot of money in a short time period
   b. Activities where people make a lot of money of a long time period
   c. Activities that generate food and/or income while maintaining the productivity of the natural resource base
   d. All activities that generate food and/or income

Field exercise 1a: Natural resources are managed together

Objective:

After this exercise the participants will be able to:

- Demonstrate the importance of proper and fair management of natural resources.

Equipment needed:

- A pitcher of water (or some similar container) and a drinking glass.

Expected output:

- Group members have a better understanding of their needs and responsibilities in regard to managing the natural resources in their community.

Time required:

20 to 30 minutes

Preparation:

Obtain the water pitcher and water glass before the group meets. Review the scenario that will be presented to the group and prepare some questions to guide the discussion.

Suggested procedure:

1. Give a pitcher of water and a glass to one member of the group. Tell the group that this water represents all the drinking water in the community. It can be renewed from rainfall collected off the roof of the nearest house. The person holding the water and the glass has total control over the water that is collected, and how it is shared among the group.
2. Lead the group through a series of questions. You may use the sample questions below or use other questions that are more appropriate for your local context. Pose a question, allow several participants to give answers and lead a discussion around their answers. Some sample questions:
    - Do you think that the person who controls the water should share the water with other members of the group equally? If yes, why?
    - Should this person make sure that the pitcher is always full and that water is always available for the community? If yes, why?
    - How would the group feel if the pitcher broke and the person did not fix it? Now all the water is running off the roof and is not being collected for the group.

3. Tell participants that every person in the community is holding this pitcher – every person is responsible for how water is managed in their community. Now help the participants discuss how they capture and manage rainfall in their area. Some sample questions:
    - Do you feel you collect and manage water well? Why or why not?
    - Does a lot of rainwater run away, or is it being collected? How?
    - When the water flows into streams and out of the community what color is it? Does it carry away a lot of soil?
    - When they grow up, will your children have healthy water resources and good water management practices so that their pitcher never breaks?

Lesson 2. The water cycle

In this lesson you will learn:

- About the water cycle and the different ways in which water circulates on our planet.
- About the key problems associated with water and water movement and some of the causes behind these problems.

Water is essential for all life – for people, plants and animals. How much water we have and how we use this water determines the productivity of our land – how many people, plants and animals it can support. Water is not created or destroyed. There is a fixed amount of water on the earth that flows in a cycle.

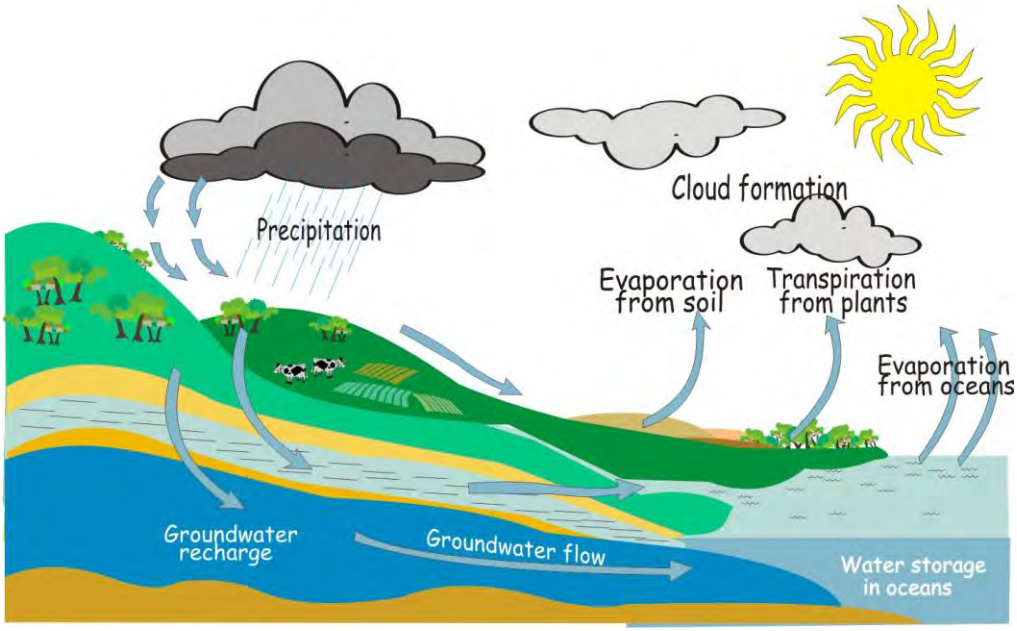
Water is a very valuable and limited resource!

The water cycle

The water cycle is term used to describe the constant movement of water on, above, and below the surface of the Earth. In the cycle, the water moves from the small creek that the farmer uses to irrigate its plot, to large rivers and oceans. The water also goes through different changes including liquid (rivers), solid (ice), and gas (vapor).

- Put a glass of water on the table and ask the group how old it is. The answer: It is almost as old as the earth.
- On the flipchart (or chalkboard or floor) draw a tree, an animal, a cloud, a lake, a plot of land. Talk to the participants about the water cycle, highlighting that water goes from one into the next in a circle. Water does not stop; water is not made or destroyed. It just keeps changing location.

Box 1. Visualizing the water cycle

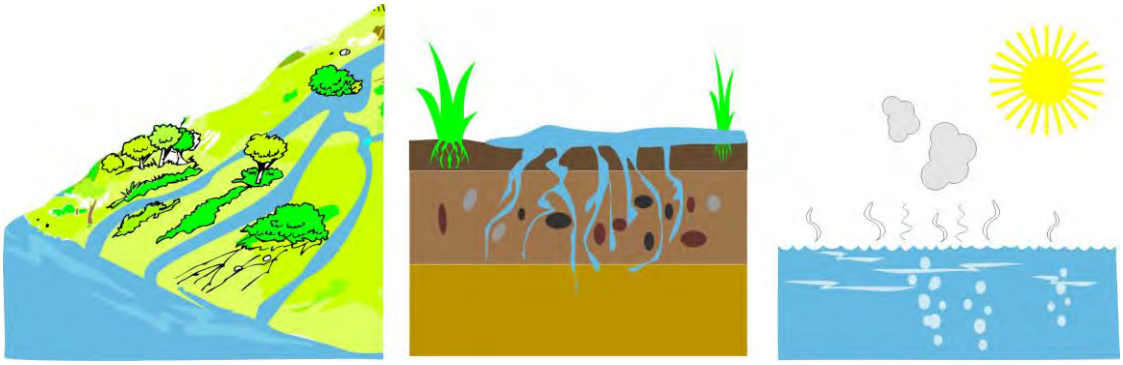
How 

water

moves off the land

For farmers the most important part of the water cycle is what happens to the rainwater once it reaches the soil. After it rains, the water that falls on the fields can do a combination of these three things:

1. **Surface runoff:** It can move across the surface of the field and go into a ditch, stream, or river.
2. **Infiltration:** It can seep into the soil and go underground.
3. **Evaporate:** because of effects of the heat and the sun, it can also vaporize and return to the atmosphere.



The water that evaporates back up into the sky is lost and cannot be used until it falls again as rain. The water that sinks into the soil is used by the plants and other life forms in the soil. For farmers, it is therefore extremely important to capture and hold as much water in the soil as possible. Water that moves off the surface of the soil may still be captured in dams, or it may move into streams and rivers. If this water moves too fast, it can have very harmful effects, causing soil erosion or flooding. It is therefore important to make sure that this water moves slowly off the surface of the land. Slowing the movement of water across the surface of the soil also gives it more time to sink in, thus it serves to both prevent erosion and improve infiltration of water into the soil.

Essential for supporting life and preserving healthy farming environments, water needs to be retained and used as productively as possible. This is particularly pressing in areas that do not receive regular rainfall, suffer from long dry seasons, or experience particularly heavy and short wet periods. The best and most commonly used method is to collect as much rainfall as possible, either in the soil or in reservoirs (like small dams or other types of large containers).

All of the water that runs off the fields is water that could have been used for production or in your homes, gardens or fields. Watching large volumes of water flowing over your fields and out of your village is almost like watching money flow out of your community.

Uncontrolled water flow can lead to a number of very serious problems: **erosion, mudslides, flooding,** and **pollution**.

Erosion

Erosion is caused by water that runs off the soil surface too quickly and carries away thesoil from fields and other unprotected areas (like grazing lands). This is one of the biggest dangers to agricultural production. The best layer of soil for growing crops is the topmost layer, called topsoil. When water carries soil off the field – especially when the topsoil is lost – productivity goes down quickly as the topsoil stores much of the nutrients and minerals crops need to thrive. Preventing soil erosion, both in your fields and in other natural areas (like communal grazing areas), is absolutely essential for farming and for sustaining lives and livelihoods.

Water that contains a lot of eroded soil is not healthy for human consumption and not very useful for domestic use. Water that has large quantities of soil also poses problems for fish and other organisms, which can struggle to multiply and even to survive in such water. Streams, rivers and dams are thus less productive, and if the problem persists it can endanger livelihoods.

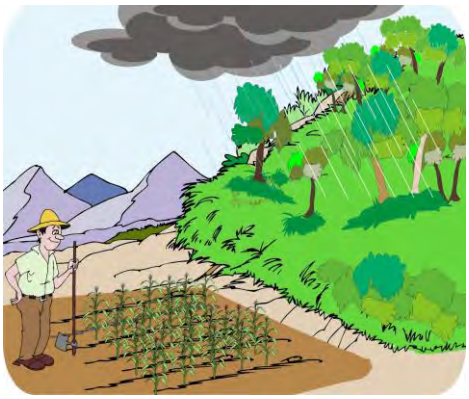
Mudslides

The roots of trees, grass, and other plants hold the soil in place on hillsides and sloping land. In areas where the slopes are steep and the trees and grass have been removed, this protection does not longer exist. If there is a period of heavy rains, the soil can fill up with water and slide downslope as mud. When a large area of land is affected, this movement turns into a mudslide. Whole plots of land and entire sides of hills can slide downhill, often strong and large enough to destroy houses and kill people in its path.

Flooding

If large amounts of water run off the fields too quickly, they accumulate in natural and artificial reservoirs (like rivers, lakes and dams). If there is more water than the reservoir can hold, inevitably it will spill over the bank and cause flooding. People are in danger of being swept away and drowning in the flowing current. Large numbers of livestock and plants also perish in massive floods. Farmers with fields in river valleys are particularly susceptible to flooding. In addition, homes, roads and other important structures are often destroyed.

When the movement of the water slows down, the soil falls to the bottom. The accumulation of these layers of soil on top of each other is called **siltation**. This is a particular problem for dams, which can fill up with soil and thus hold less and less water over time.



Causes of floods

People often think that floods are always caused by too much rainfall. However, there are additional factors that lead to frequent flooding, even when rainfall remains the same in locations where it was uncommon before.

- **Removal of trees and/or vegetation cover from slopes**
  Without cover, large quantities of water flow off the slope very quickly and end up in streams or rivers. These water reservoirs fill up beyond capacity and overflow, causing flooding. Cutting trees and removing plant cover from the slopes of hillsides can cause flooding even when rainfall remains the same.

- **Soil erosion**
  When the topsoil layer has been reduced by erosion, the remaining topsoil cannot hold as much of the rainfall as before. The water that was previously soaked up by the soil runs off the surface into ditches, streams, rivers and lakes. During heavy rains this happens quickly and causes the water basins to overflow and flood.

Keeping **trees** and **grass cover** on the upper slopes to slow down runoff and **capturing more water in the soil or in small dams** are important ways to prevent or reduce flooding.

Pollution

When water runs off the soil too quickly, it also carries with it everything that was in the surface. This may include chemicals, trash, disease organisms, or other pollutants. For example, if a field was recently sprayed with insecticides or fertilized with manure, heavy rains will wash these particles down into the local dam. Dangerous chemicals and manure can pollute the source of drinking water for the community and can kill off organisms that live in the water (some of these organisms are very

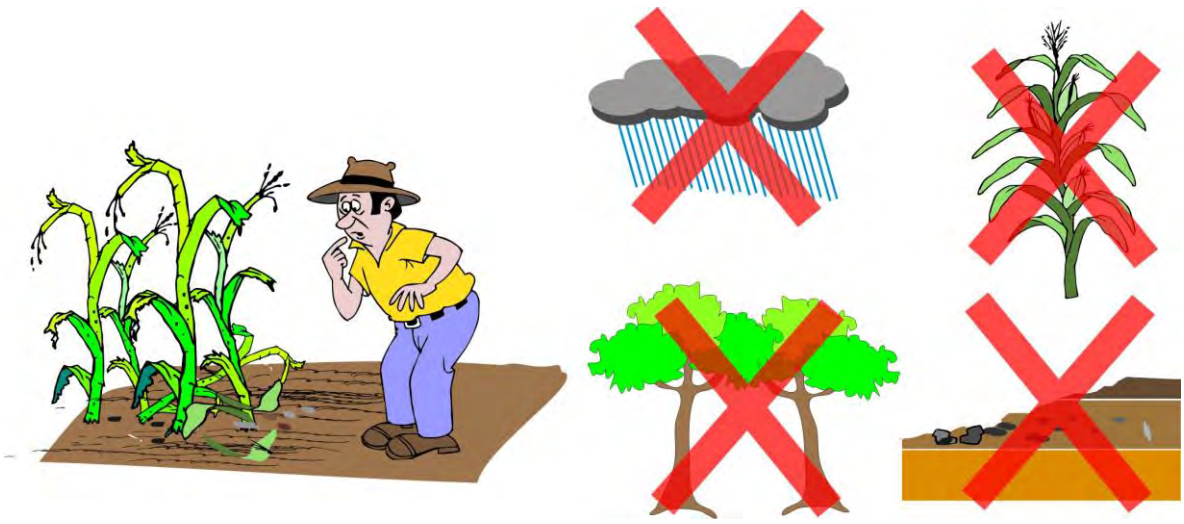
important for livelihoods – like fish). Reducing runoff can greatly reduce the level of pollution.

Drought

We usually think of drought as not having enough water – either for crop growth, for grazing plants and drinking water for livestock, or for people (drinking, bathing, and other household use). Normally, we blame it on lack of rainfall, but it has also other causes:

- **Less rainfall than normal** or **poor distribution of rainfall** (for example, very little rain at the beginning of the rainy season and a huge amount of rain at the end of the season).
- **Not having enough topsoil** to store water between rain events. Because of the negative effects of erosion it may seem that there is less rainfall, when in fact the level of rainfall has remained the same. There is just not enough soil to hold it for a long time.
- A **hardpan** can prevent the water from seeping into the soil below. A hardpan is a tightly packed, very hard layer of soil. It can be created, for example, by plowing a field often and to the same depth each time.
- **Not having adequate soil cover**, for example, because all trees in a particular area were cut down. This allows water to run off the surface of the soil too quickly, before it has enough time to sink in and be stored for use by the plants. This accounts for much of the lost rainfall.
- **Certain types of soil** do not hold water as well as others. Light sandy soils hold less water than heavy clay soils. Light soils hold water better when they contain a lot of organic matter. When the organic matter is lost (for example through excessive plowing), these soils can hold considerably less water than before.
- **Some crops need less water** than others (for example, maize normally requires more water than sorghum or millet). So while one type of crop looks healthy, another gives the impression that it is suffering from "drought."

When looking at "drought" examine multiple causes and pick the appropriate solution.



Conclusion

In this lesson we covered the water cycle: what it means and why is relevant to you when working in NRM project. We also looked at some of environmental impacts caused by uncontrolled water such as erosion, mudslides, and flooding. We finished the lesson by reviewing the main causes of both floods and droughts.

In the next lesson we'll talk about strategies to manage water that can be implemented at farm level.

Quiz 2. The water cycle

See Annex 1 for answers.

1. What can happen with the water that falls on our fields?

a. It can run off the surface

b. It can sink into the ground

c. It can evaporate back into the sky

d. All of the above

2. Rainwater that falls on a crop field should:

a. Sink into the soil

b. Be removed as quickly as possible

c. Be prevented from running off too quickly

d. Only a and c

e. Only a and b

3. Soil erosion is caused by:

a. Water moving too quickly over the surface of the soil

b. Water moving too slowly over the surface of the soil

c. Soil erosion is not caused by water at all

4. Soil erosion is a problem because it can lead to:

a. More floods

b. More droughts

c. Pollution of drinking water

d. Lower soil fertility and lower crop yields

e. All of the above

Field exercise 2a. Viewing soil erosion in runoff water

In this exercise, group members will learn a simple way of assessing the impact of erosion by comparing the amount of soil being carried in a stream or river.

Objective

After this exercise the participants will be able to:

- Explain the meaning of erosion by demonstrating that muddy rivers means water flowing out of farmers' fields carrying precious soil.
- Assess the extent of this erosion.

Equipment needed

- A clear glass container (like a water glass).

Expected outputs

- Group members understand the implications of dirty runoff water, and know how to obtain a relative measure of the soil loss (erosion).

Time

30 to 45 minutes

Preparation

This exercise is best conducted during the rainy season when a nearby water source is carrying dirty runoff water. Look for any potential streams ahead of the meeting.

Suggested procedure

1. Collect a sample of water in the clear glass container from the stream or water body you identified in the preparation. Display this glass where the group can see it during your discussion.
2. Ask whether they have observed a difference in the color of the water of local streams/rivers before, during, and after the rains. Why is the color different? Lead the conversation to the point where group members recognize that the darker color usually means that the water is carrying more soil. Discuss where this soil comes from.
3. After about 30 minutes, look again at the sample of water that was collected at the beginning of the discussion. See if the water has cleared up at all, and if some soil has settled in the bottom as mud. Discuss what you see with the group members. Suggest that

they do this simple test on their own close to their farm to see how much soil is being carried away by runoff water.

Note: if you cannot find a nearby source of muddy water, gather three clear bottles and fill them up with water. Then, ask farmers to add soil, shake the bottles, and try to replicate the color of the rivers in the area. Use the different types of water to discuss the questions cover in this field exercise.

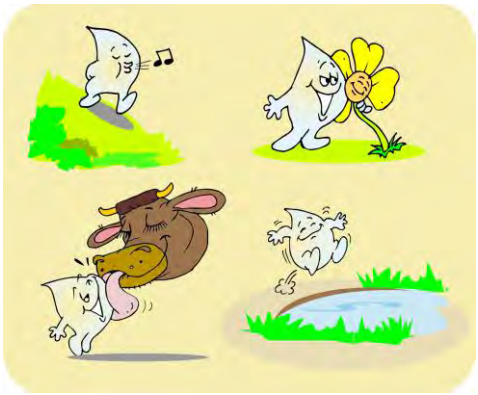
Questions to stimulate discussion

- How dark is the runoff water? Probe for different gradations or local terms.
- What is the color of the runoff water (red, brown, gray)? What does the different color mean?

Lesson 3. Managing water

In this lesson you will learn:

- The different strategies for managing water: capturing rainfall, increasing infiltration, and preventing landslides.



Often the same approaches are used to manage different kinds of threats from water. The main goals are to:

- **Capture** more of the rain in the soil where it falls, or in small dams;
- Make sure that excess water moves off the slopes **slowly** and **safely;**
- Store and use water for **irrigation** if possible.

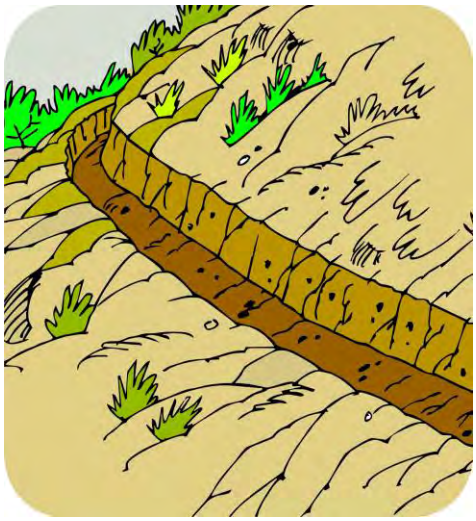
There are multiple ways to manage runoff and stop soil erosion, and to protect the land against droughts, floods, and mudslides.

Water should always *walk* – not run – off the slopes

Capture as much of the rainfall as possible and use it effectively

Collect surface water runoff in dams and use **water harvesting** techniques to trap rain and direct it into a storage structures. For example, in Africa "Zai pits" are often used to collect water around individual plants. These are small holes filled with compost, stems, and manure, and then used to retain water from the rainy season in preparation for the dry months.

Slow runoff and increase infiltration into the soil by using various types of **ground cover.** Ground cover can be provided naturally by trees, grass, or other types of vegetation, or by laying non-living material, such as corn stalks or lines of stone or trash, along the contour. A "contour" is an imaginary line that runs horizontally across the slope. It stays at the same level, i.e. does not go up or down the slope.



Another way to slow or stop runoff is to build **contour trenches** along the slope. Sometimes these contour trenches may also include shallow pits that trap additional water, making sure that it seeps into the ground. These are called **infiltration pits**. Contour trenches have to be properly laid out and constructed, or they may actually

make the water damage worse. It is necessary to use special equipment to lay out a contour line precisely, so it is important to obtain expert advice before constructing contour trenches.

Increase the amount of water that the soil can hold. One strategy is to preserve as much of the soil on the field as possible by **reducing erosion**. Another way is to remove plough pans by using a ripper or subsoiler to break up hardened layers of soil. Also **increasing** the amount of **organic matter** in the soil increases water uptake. Organic matter is any material that was formerly living or produced by something living. This can be done by adding animal manure or any living or dead plant material to the soil.

Reduce evaporation and increase infiltration

Covering the soil surface with dead plant material is called **mulching**, and it greatly reduces evaporation of water from the surface of the soil. It's like putting a "lid" on the soil to hold the water in. It also has three other key benefits: (1) it **reduces weed growth** (it prevents sunlight from reaching the soil surface); (2) it **increases organic content** of the soil (as the plant material breaks down, it slowly filters into the soil); and (3) it **decreases the force** with which the rain hits the surface of the soil, and **slows down** the movement of water across the soil surface. This reduces erosion and increases the infiltration of water into the soil.

Prevent landslides by using trees and grasses to stabilize the soil

Plant **roots hold the soil together**, especially on sloping land where it might otherwise slide downward during heavy rainfall. **Tree roots are especially good** because they are stronger and go deeper than the roots of smaller grasses and shrubs. Making sure that steep hillsides remain covered with trees and other plant life is the best way to protect against mudslides.

Conclusion

Managing water is was the central theme of this lesson. We showed you some effective techniques to capture as much rainfall as possible, such as increasing mulch and the amount of organic matter, removing plough pans, and planting trees and grasses to reduce erosion. In the next lesson we'll introduce the concept of watershed and how it can be used in NRM.

Quiz 3. Managing water

See Annex 1 for answers.

1. Key strategies for managing rainwater include:

a. Capturing rainwater in the soil where it falls

b. Making sure excess water *walks* – not *runs* – off the surface

c. Making sure that excess water evaporates safely back into the atmosphere

d. Only a and c

e. Only a and b

2. Options for managing water on a slope include:

a. Keep the soil covered with grass and/or trees

b. Remove all ground cover on the soil

c. Make contour trenches across the slope

d. Make contour trenches up and down the slope

e. Only a and c

f. Only b and d

3. True or False:

a. Organic matter in the soil increases the water holding capacity of the soil.

b. Stopping soil erosion will increase the capacity of the soil to hold water.

c. Mulching the soil surface will increase rainfall infiltration and decrease evaporation.

Field exercise 3a. The importance of soil cover

Objective:

After this exercise the participants will be able to:

- Demonstrate the importance of soil cover.

Equipment needed:

- A bucket of water (and water source) and a small piece of heavy cloth (or carpet), at least one meter square. Find a location that has easily accessible bare soil that is slightly sloping and that can be wetted.

Expected output:

- Group members have increased awareness of the importance and benefits of maintaining soil cover (either live cover or mulch).

Time required:

20 to 30 minutes

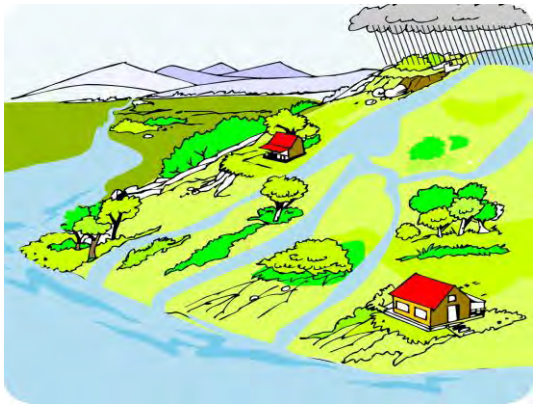
Preparation:

Practice the exercise before the presentation to make sure that the cloth or carpet being used, and the rate at which the water is poured, produce different effects on the soil (with and without cover). The effect should be clearly visible for the group members.

Suggested procedure:

1. Gather the group at the selected site and pour the water from the bucket directly onto the unprotected soil. Ask the group members to describe what they see: What is happening to the water? (They should see some movement of soil and quite a lot of water running off the soil surface).
2. Place the heavy cloth or piece of carpet on the unprotected soil surface next to the area where the first bucket of water was poured. Pour a second bucket of water onto the heavy cloth or carpet. Ask the group to describe what they see: What is happening to the water? Is it behaving differently from the first example? (They should observe that [a] the surface of the soil is disturbed much less and [b] the cloth has retained much of the water, i.e. there is less "run-off").
3. Lead the group in a short discussion on the effects of soil cover on water movement. Ask: What are some examples of natural cover? (Point to nearby trees, shrubs, grass or mulch)? How can we replace natural cover? (For example, by planting trees, mulching).

Lesson 4. Watersheds and watershed management



In this lesson you will learn:

- What is a watershed.
- Why it is important to consider water management across the entire watershed.
- Some root causes of erosion and ways to address it.
- Ways to identify and address problems on the watershed level.

A "**watershed**" is an area from which all of the rainfall drains into the same place (stream, river or ocean). Watersheds can be large, covering thousands of hectares and many smaller water bodies, or even very small, just a few square meters that all drain into one gully or stream. Even very flat areas are part of a watershed. Regardless of size, a few basic management concepts are useful for all watersheds. It is important. This section will discuss **how to identify problem areas** within a watershed and how to **manage rainfall** across the **entire watershed.**

Regulate the flow of water across the entire watershed: from top to bottom and from one side to the other.

Managing water across the entire watershed

It is impossible to manage one part of a watershed effectively without looking at **upslope and downslope.** For example, if our field is on the lower part of a slope and there are no trees above, heavy rains will result in large volumes of water pouring down onto the field. This may cause serious erosion and damage. Also, if we do not consider the effects of the water leaving our field, we may be causing problems further down the slope without knowing. To prevent this we could build a big contour trench across the top part of our field to protect it from incoming water. The trench will catch all of this water and divert it away from our field. But, if it does not guide the water slowly and safely away into the stream or river of the watershed, it can make a big gully or cause erosion on someone else's field downslope.

Think of the effects of your water management –
Think of the entire watershed.

What causes soil erosion?

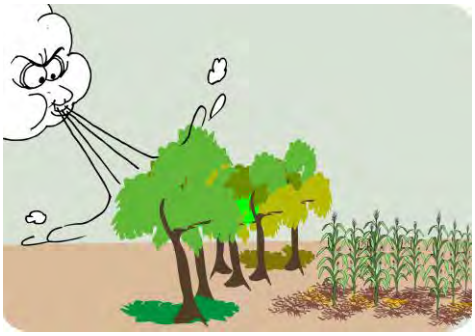
- **Weather.** Wind and water can blow or wash soil away, the more fierce the weather the more soil is lost. Soft breezes leave the soil in place and gentle rains soak slowly into the soil, without washing it away.
- **Slopes.** Soil on sloped land erodes faster than soil on flat land. Steep slopes lose more soil than moderate slopes. Longer slopes lose more soil than shorter slopes because water builds up speed and force as it moves down an uninterrupted slope.
- **Soil cover.** Bare soils erode much more easily and quickly than soils covered with plants, such as tall grasses, mature crops or thick groves of trees.
- **Type of soil cover.** Soils covered with a thick tree cover or grasses that are never cut lose very little soil. Land that is used for annual crops (like maize, sorghum, millet and beans) can lose topsoil more easily, especially if it is left uncovered during the dry season and the early part of the rainy season. Erosion also happens when land is cleared for planting and at the beginning of the rainy season, before plants grow and provide a protective cover over the land.
- **Soil type.** Soils with many fine particles blow and wash away faster than soils with sand particles, which are somewhat larger and heavier.

How to reduce erosion

There are two main strategies for combating both water and wind erosion. The first one is to use **physical interventions** that will limit the force and the impact of water and wind on the soil. They include using mulches; building terraces; plugging gullies; building dams, check dams and reservoirs; constructing infiltration and diversion ditches; using Zai holes as planting areas, and many others. The other strategy is to use **biological interventions** to achieve the same effect. They include planting windbreak lines of trees; planting grass strips or shrubs along the contour line; using crop cover for the soil (often deep-rooted legumes planted with widely spaced cereals); crop rotation; keeping permanent vegetation on steep slopes – perennials like forage

legumes or trees (fruit, coffee, tea, nuts etc.), planting crops that capture water in their biomass, and many others.

Wind erosion happens due to strong winds that blow over unprotected, exposed lots of land. The wind picks up the small soil particles and disperses them over a wide area.



Place wind breaks – These are usually lines of trees or other tall plants that are planted perpendicular to the direction of the incoming wind. How far apart the rows are planted depends on the height of the plants and the usual force of the wind.

Cover the soil – Keeping the soil covered with live plants or with mulch also fights erosion.

Water erosion happens when water runs rapidly over the surface of the soil, carrying with it soil particles. The steeper the slope and the longer field, the faster the water will flow and the more erosion it will cause. Reducing erosion by water usually involves either slowing down the flow of water or channeling the excess water safely off the threatened area.

- **Build trenches along the contour of the slope.** This trench will capture and channel excess water away from the field.
- **Place barriers along the contour of the slope.** These barriers can be constructed by piling stones or brush along the contour of the slope. This will either block or slow down the movement of water. Also natural barriers can be planted along the contours of the slope, such as trees or permanent grass strips.

- **Plug gullies.** As soon as you notice large crevices in the earth, made by flowing water after heavy rains, take action. Fill them up with either stones, heavy piles of brush or fences, for example bamboo stems with vines woven between them.
- **Cover the soil.** Keep the soil surface covered either with mulch or with live plants, like grass or a green manure crop.

How to identify problem areas in a watershed

Problem areas or **hotspots** are usually caused by rainfall runoff that is moving too fast and therefore causing soil erosion. Identifying problem areas is often as simple as looking for **signs of erosion** or **risk of erosion**:

- Areas of **bare soil on a slope** with no vegetation. Such areas are vulnerable to erosion and are most likely already suffering from it.
- Places where **gullies** are forming – especially if they are getting bigger.
- Areas where **plant roots are exposed**.

- Areas where the **soil surface is covered with stones** (meaning that most of the topsoil has been eroded).
- Areas where **plowing brings up subsoil or stones,** while before it turned up only good soil.
- Areas where **heavy rain turns streams muddy**, or where a lot of soil accumulates at the bottom of the slope.

How to manage rainfall within a watershed

The most effective way to manage soil and water resources is to **work across the entire watershed**. Using this approach, you can eliminate soil erosion almost completely and capture the maximum amount of rainfall – either in the soil or in small dams. Capturing surface water in small dams also opens up the possibility of irrigation farming and other commercial activities, such as fish production.

The technical solutions for managing water movement within a watershed are described in detail in Lesson 5. Three of the most common and important tools for managing water movement include:

- **Keeping the soil covered** at all times by using grass, trees or crops (or the remains of the previous crop). Covering the soil with dead plant matter protects against evaporation of water from the soil surface and also slows the movement of water across the soil surface.
- **Creating barriers along the contour lines** of a slope, such as stone barriers or live barriers (trees, shrubs or special species of grasses). They help slow down water movement and keep the soil on the contour edge compact and strong.
- **Digging contour trenches** along the contour lines of a slope. These ditches capture the water and transport it safely to dams or streams.

When building barriers or ditches along contour lines it is important to make sure that the contour lines are properly marked. If this is not done well, it may instead concentrate the water in some areas and actually make the problems even worse.

As most of the time watershed areas are larger than individual farms, **cooperation is essential**. Developing a management plan for the whole watershed requires all farmers and stakeholders who use the area to communicate, consult one another, and work together. It may also require the involvement of local government bodies. The first step in promoting cooperation is to identify and build awareness among the local population about the different stakeholders in the watershed and their roles in a water management plan.

All farmers jointly manage the water in the watershed together.

Upstream and downstream issues

Surface or ground water is used many times by many users before it reaches the ocean or evaporates. The people who use the water from a river before us are **upstream users**. We want those people to **respect** our rights and **need for clean and safe water**. This means that they should not use all of it. It also means that they should not pollute the water after they have used it.

Those who use the water after us are **downstream users**, and they deserve the same considerations that we want to receive. We should make sure that they receive enough water that is clean and safe to use. Various **national** and **local laws** regulate water use – especially surface water in streams, rivers and dams. We need to be aware of those laws and respect them.

Conclusion

This lesson introduced you to the concept of watershed and the importance of understanding what is happening upslope and downslope. With that framework in mind, we delved deeper into some of the causes of erosion and ways to tackle them. We also gave you some clues about what to look for when identifying problems within a watershed (such as gullies, exposed roots, muddy streams, etc.) and what to do address them. The last section covered the importance of thinking about the watershed as one unit, where the needs and responsibilities of upstream and downstream users need to be balanced. In lesson five we leave water and start talking about soils.

Quiz 4. Watersheds and watershed management

See Annex 1 for answers.

1. A watershed is:

a. A huge area with a river running through it

b. A hillside where all the water runs off when it rains

c. An area where all the rain that falls drains into the same body of water

d. The land and all the resources between two bodies of water

2. True or False:

It is possible to effectively manage only a small part of a watershed without having to worry about anything outside your particular area?

3. You can identify "problem areas" in a watershed by looking for:

a. Areas of bare soil on a slope

b. Gullies forming and getting bigger

c. Surface areas covered with small and medium sized stones

d. All of the above

e. None of the above

4. Ways that you can effectively manage water within a watershed include the following:

a. Ensure that the soil is never covered with anything – living or dead

b. Don't create any barriers to slow down the flow of water on the slope

c. Never dig any contour trenches across the slope

d. Channel all of the rainfall run-off into existing gullies

e. None of the above

5. True or False:

We only need to manage the water we are using in our own immediate environment. People who live upstream or downstream from us need to look after themselves

Field exercise 4a. Seek out a problem area in your local watershed

Objective:

After this exercise the participants will be able to:

- Identify "problem areas" in watersheds

Equipment needed:

- None

Expected output:

- Group members gain practical experience in identifying problem areas in their local watersheds.

Time required:

1 hour

Preparation:

The facilitator should scout the environment in the area near where the group meets and identify at least one or preferably two clear "problem areas" that can be visited during the group's transect walk. The problems areas should be very easily visible and accessible.

Suggested procedure:

1. After the regular meeting, tell the group that they are going to go for a walk and look for problem areas in their local watersheds. Based on the information from the lesson discuss some of the more prominent signs of potential problems (bare soil on slopes, exposed plant roots, gullies, very muddy streams after heavy rains etc.). Explain that you have already identified some areas, but the participants have the task to identify these problem areas by themselves. The facilitator will only tell them about a problem area if the group members fail to identify it as they walk past.
2. Once the participants have correctly identified a problem area ask them to discuss the causes of the problem and measures to address the problem.
3. Try to have the group find at least two different kinds of problem areas during the walk.

Lesson 5. Soil composition

In this lesson you will learn:

- What is topsoil and why it is important
- About the role of organic matter in plant growth, and different strategies for replacing organic matter in the soil
- The characteristics of the different types of soil (sand, silt, clay and loam)

What is soil and what does it do?

Soil is the home of plants, providing them with water and food (**nutrients**). It also keeps plants stable and strong by anchoring their roots. Soil is made up of different layers, but the most important for plant growth is the darker top layer, called **topsoil**. It holds many of the essential nutrients plants need. It contains pathways for roots to grow and holds the water and air that roots use to survive. The deeper this topsoil layer goes the more crops can be produced. Deeper topsoil can hold more nutrients and retains water longer during dry spells. But it is very vulnerable to wind and water which can quickly wash or blow it away.

It takes hundreds of years to create one centimeter of topsoil!

Topsoil layer

Topsoil has more **organic matter** than the layers below. Organic matter is made up of living and dead plant roots, rotting stems, leaves, animal manure, and all the small animals that live in the soil. Small micro-organisms and larger soil animals (like earthworms, beetles, and termites) transform organic matter into rich topsoil, providing important nutrients for plants. It is a perpetual cycle. More organic matter means more soil animals, which transform organic matter into even more nutrients and makes the topsoil very fertile.

You can increase the number of soil animals by: limiting the use of agro-chemicals, increasing plant organic matter, adding compost to the soil, producing vermiculture (worm compost), growing green manure, and/or rotating crops. Field exercise 5 describes how to measure the population of soil animals in topsoil. Having more organic matter also helps to trap more moisture during dry periods and helps drain excess water faster after heavy rainfall..

Sometimes there is a thin, hard compact layer of soil right below the topsoil called a **plowpan**. This happens when plowing or hoeing the soil to the same depth each year. Plowpan are undesirable because they can block root growth, limit oxygen access to roots, and slow down or prevent water from seeping through the topsoil.. The best to prevent them is to work the soil to different depths or avoid tilling the soil altogether.

Box 2. Signs that the topsoil is depleted or gone

- When you dig in your field you find that the soil closest to the surface is made up of a very thin dark layer or no dark layer at all.
- Your fields have been producing very low crop yields or only scattered, hardy weeds.

- On land that is sloped, if you see that the soil level has built up and is higher on one side of tree trunks or fence posts than the downslope side, this signals erosion of topsoil.
- The surface of the soil may be rocky and full of stones, sometimes called an "Armor layer."

Why is organic matter important?

As plants grow, they take from the soil important nutrients, such as nitrogen (N), phosphorus (P) and potassium (K). Organic matter provides these and other essential nutrients. It also builds up the structure of the soil so that it is easier for plants to grow in it. Organic matter provides food for the soils' micro- and macro-fauna, which in turn increases the soil's capacity to hold water (like a sponge). Because organic matter is so beneficial for the soil, it is important to implement activities that protect it and increases ints availability every year. In this way, soils can stay rich and healthy for next year's crop.

Adding **commercial fertilizer** is another way to increase soil fertility. But it has some disadvantages. It is expensive and does not contain all the nutrients plants need. Commercial fertilizer does not improve the soil structure or its capacity to hold water. Applying too much artificial N-P-K fertilizer too often will kill important soil animals and contaminate downstream water sources. However, if the soil is severely depleted of nutrients, fertilizer may be a necessary measure. Commercial fertilizer can trigger new plant growth, and thus give the organic matter that can be introduced back into the soil. Over time, poor soils can be transformed into healthy soils by adding both commercial fertilizer and organic matter.

How to protect the existing organic matter?

- **Do not use burning to clear land for crops**. Burning weeds and vegetation takes organic matter out of the soil. Unburned soils have twice the number of important nutrients (carbon and nitrogen) and twice the number of soil animals. Burned soils also degrade faster, producing meager – if any – crops. Instead, once the land has been cleared of trees and is cropped from year to year, the best way to clear it is manually or with animal traction and a simple plough. The best strategy is to adopt a minimum tillage system.

- **Protect soil cover and organic matter from livestock.** If livestock are allowed to graze freely unsupervised, they will often eat or trample much of the plant material that would otherwise remain in place and thus protect the soil against erosion. The same plants will add organic matter to the soil when they die. One way to

prevent livestock damage to plant life is to control free grazing by carefully tending to your livestock. This makes sure they do not overgraze an area or destroy valuable vegetation. Another solution is called "cut and carry forage." You harvest the plants that animals eat (called forage) and take it to penned or tied animals. A third method is to identify areas away from crops where animals can graze freely, such as pastures or fenced land.

How to replace organic matter?

- **Mulch.** It is made by collecting various residues of dead plants (leaves, stalks, fruits) and leaving this layer of dead plant matter on the surface of the soil. It helps control weeds, adds nutrients and keeps the soil damp longer.

- **Green manure.** Certain crops or plants increase one of the essential minerals in the soil – nitrogen. These crops are grown primarily for the purpose of improving soil fertility. Usually they are cut and left on the surface of the soil while still "green." Sometimes a green manure crop can be grown next to a cereal crop (like maize, sorghum or millet). Other times the dead leaves, roots and stems of a green manure crop can be left on the soil surface before planting the cereal, or directly incorporated into the topsoil. Green manure plants include beans, peas, cowpeas, peanuts (groundnuts), clover, alfalfa and the leaves of some trees (for example, *Leucaena leucocephala* and *Gliricidia sepium*).

- **Livestock manure.** When animals are penned at night on a bed of straw, their wastes can be collected with the straw from time to time and mixed into topsoil or added to a compost pile.
- **Compost.** It is a mix of organic refuse materials: soil, dead leaves, stalks and other plant material, vegetable scraps and ash from cooking fires, eggshells and animal manure. Compost is collected in a pit or in a heap, and it is mixed and lightly watered every week or two.

Compost breaks down into a rich, dark mixture concentrated nutrients, bomb" and can be with a seed or mixed growing plants.

called **humus**. Full of richly humus is like a "fertility applied to planting holes into the soil near the roots of

Soil texture

Soil texture refers to the size of the particles in the soil. It varies from place to place, even in the same plot. Some soils are stony, some are sandy and others are sticky and get muddy when it rains. Large soil particles are **sand**, very small particles are **clay**. Particles that are between sand and clay in size are called **silt**. Soils that have a more or less equal amount of sand, silt and clay are called **loam**. Sandy soils have more sand than other particles and clay soils have more clay.

Characteristics of sandy soil

Sandy soils are gritty, rough and light in color. The grains do not stick together like clay and do not provide solid grounding for plant roots. You will often find sandy soils near river beds or coasts. Sandy soils are easy to work, but water drains through them quickly and they are not very fertile. Most plants have a hard time growing in sandy soils, especially if there is no silt or clay mixed in with the sandy soil.

Sandy soils can be improved by adding a lot of organic matter: plant residue, leaves, roots and manure. One way is to grow a cover crop and work it back into the soil. You could just chop it with a machete and leave it on the surface as mulch, while the roots provide organic matter in the soil.

When organic matter completely decomposes, it becomes the dark and rich **humus** mentioned above. Humus retains water, holds nutrients and binds soil particles together, thus providing the structure that plants need.

It is possible that on sandy soils you will not be able to produce enough plant biomass to start the cycle of returning organic matter to the soil. You may need to use commercial fertilizer to produce the first plants, or add large amounts of manure or compost. Also, you can plant leafy trees or bushes around the plot borders, so that their leaves can drop onto the field and provide additional organic matter.

A technique used in dry areas with sandy or clay soils is planting in a Zai hole. A hole of about one meter in diameter is dug and filled with compost to retain the water and provide nutrients. Then the seed or seedling is planted. Commonly, Zai holes are surrounded by a low mound of soil in the shape of a half moon. The soil is molded so that it captures water flowing over the surface of the field into the Zai hole.

Characteristics of clay soil

Clay soils are made up of the smallest particles and can be brown, black or red. Soils with a lot of clay are a hard mass when dry and crack on the surface. On the other hand, they hold water so well that they become muddy when wet and drain poorly. When it is very wet, plant roots have a difficult time getting enough air. When the soil is very dry, the roots have difficulty finding channels to move through. Clay soils are generally very fertile. Wet clay particles stick together

so well that they can be hard to plow but can be used to make pottery or bricks. When dry, clay is very vulnerable to erosion by wind.

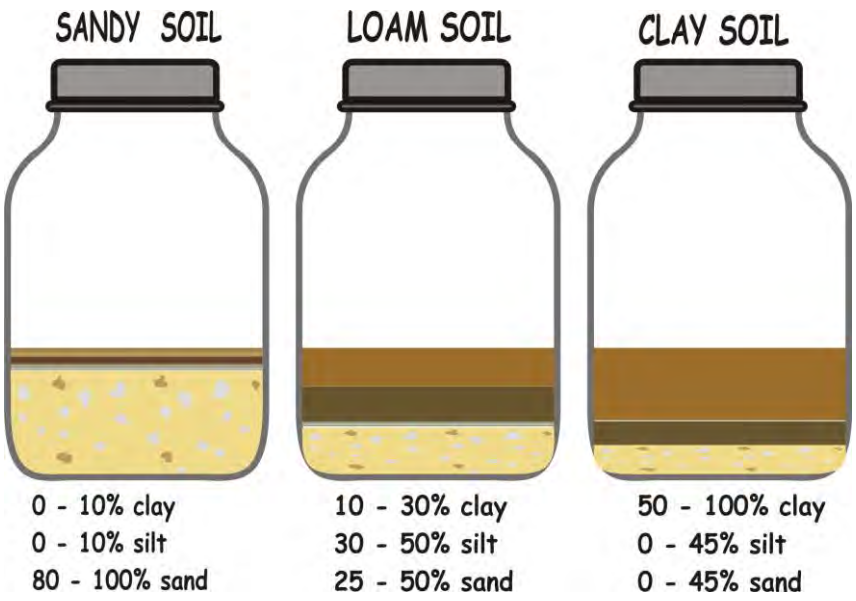
Clay soils can be improved by adding organic matter, which helps to bind it together and form clumps called **aggregates.** The channels that form around the aggregates provide better water drainage and air circulation as well as the space that the roots need to grow. The drainage in clay soils can also be improved by digging drainage ditches, planting crops on ridges next to **furrows**, or areas between the crop rows that are lower than the crop row. Tillage can also break up the clay so that plants can grow.

Characteristics of silty soil

Silty soils are neither clayey nor sandy; they are somewhere in-between. They do not get as muddy as clay and are very fertile. They can become compacted if cultivated when wet. They do not crack at the surface when dry.

Characteristics of loam soil

Loam soils contain a balanced mix of sand, silt and clay. For this reason they are one of the best soils for agriculture. They retain water but also drain well and are easy to plow. They hold nutrients and provide an ideal home for soil animals and have a good balance of soil moisture, air and nutrients.



Conclusion

In this section we covered the critical role of soils, particularly the top layer. We discussed what organic matter is made off and why is so important to the health of our crops. We also gave you some practical ideas about how to protect and increase organic matter. The lesson ends by covering the main characteristics of sandy, silty, and loamy soil – the three main types of soil texture. In the next lesson, we'll discuss how soils interact with nutrients.

Quiz 5. Soil composition

See Annex 1 for answers.

1. What do plants get from soil?

a. Nutrients

b. Water

c. Air

d. All of the above

2. True or False:

a. Most soil nutrients are found in the subsoil.

b. Topsoil is easily replaced.

c. All organic matter is made up of things that are alive now or were alive at one time.

d. There is more organic matter in topsoil than in other layers of the soil.

e. Organic matter is not very good for the soil and one should try to get rid of it.

3. Ways to add more organic matter to soil include:

a. Add animal manure

b. Make and add compost

c. Add mulch

d. All of the above

e. Only a and c

4. True or False:

a. The three main textures of soil are sand, silt and organic matter

b. The best soils are "loamy soils" which have a balanced mix of sand, silt and organic matter particles

Field exercise 5a: Measuring soil animals

Objective:

After this exercise the participants will be able to:

- Measure the population of soil animals in the topsoil, a key indicator of soil health and its ability to produce crops.

Equipment needed:

- Aluminum can or homemade square metal frame.
- White or light colored cloth or sheet.
- Instruments for cutting and digging (machete, cutlass or shovel).

Expected outputs:

- Group members have learned how to measure the topsoil's macrofauna (the soil animals that are visible to the eye).

Time:

15 to 30 minutes per site measured

Preparation:

The facilitator should first make a sampling frame, using an aluminum can or a square made out of scrap metal. If using a can, you need to remove the top and bottom. The can should be big enough to hold 800 grams of soil (at least 15cm tall). If making a metal frame, you can solder 4 flat square pieces of metal (about 17cm by 17cm and 15cm tall) together to make a square frame, without a bottom or top part. The best time to carry out this exercise is after rain, when the soil is slightly damp but not very wet.

Suggested procedure:

1. Before starting the measuring exercise, spend a few moments describing how you constructed the metal square frame or the can. They may have to construct a frame on their own in order to measure topsoil quality on their own farms.
2. Push the can or metal square frame into soil, until about 3 cm of the frame are sticking out of the ground.
3. Use a machete or shovel to dig beneath and around the can of soil. Take out the can with the soil and place it on a white sheet or cloth. Separate the soil from the can.

4. Count the number of soil animals that you can see and record this number. The more soil animals that you count, the more fertile the land.
5. Use the can to take samples at other locations on the plot.
6. Tell the participants:
    - As you add more organic matter to your soil, you can return to count soil macrofauna each year at the same time with the same size can or frame. You should see the number of soil animals increase.

Note: If your soil has lots of stones or pebbles, do not use this tool.

Field exercise 5b: Measuring topsoil depth

Objective:

After this exercise the participants will be able to:

- Use two techniques to measure topsoil depth: (1) observing soil layers in a road cut in the area or (2) digging a hole on the farm plot and examining it.

Equipment needed:

- Shovel or other digging tool

Expected outputs:

- Group members know how to take topsoil measurements.

Time:

30 to 45 minutes

Preparation:

To prepare to demonstrate the first technique, find a place within easy walking distance of the group's meeting location where they can see a cross-section of the earth where it has been cut away for a road or some other construction project.

To prepare a demonstration of the second technique, dig the hole ahead of time. Continue digging until you see the color of the soil beginning to lighten. Dig to at least 50 cm, even if there is no topsoil and no color change to observe.

Suggested procedure:

1. Before looking in detail at the soil, lead the group in a discussion regarding soils in the area. Explore local names and the characteristics assigned to each soil (good/bad, poor/rich, stony/soft etc.).
2. After looking at the soil, discuss the differences you observe in the different soil layers. Note color differences, differences in size and number of stones, different depths. Connect this with the previous discussion. Ask:
    - ✓ What types of soil is visible here?
    - ✓ What are the soil's main characteristics?
3. If there is darker soil (soil with more organic matter) at the top, this is **topsoil**, also called the **A-horizon** layer. Estimate or measure the depth of the topsoil layer.

4. Explain that most crops need at least 20-25 cm of topsoil for premium production. When the topsoil is shallower, you need to add organic matter each year to maintain a good crop.
5. At the “road cut” location note the presence or absence of stones in different layers and on the soil surface. Compare the number of stones on the surface to the number of stones you see along a parallel horizontal line at the lower layers. If the number, or concentration, on the surface is greater than below, much of the topsoil has been already blown or washed away by erosion.

Field exercise 5c: Determining soil texture

Objective:

After this exercise the participants will be able to:

- Use a simple and practical system for determining soil texture.

Equipment needed:

- Some water in a container and two or three soils of different textures (these might be found near to each other in a field, or collected and brought to the meeting).

Expected output:

- Group members will learn a systematic way to compare the texture of different soils.

Time:

15 to 20 minutes

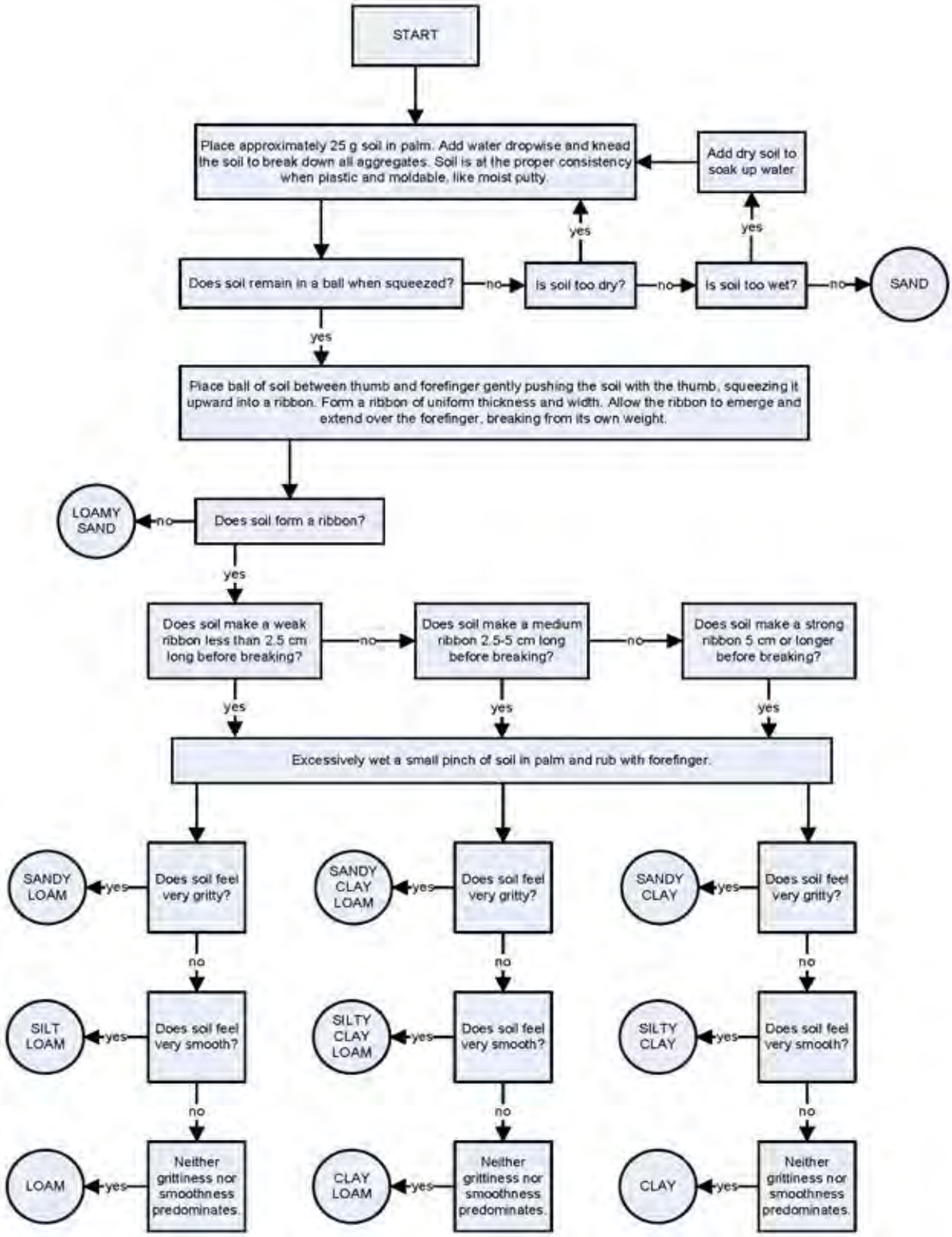
Preparation:

The facilitator should identify where the group can access soils of different textures, and should try the exercise in advance of doing it with the group.

Suggested procedure:

1. Explain to the group that they will do an exercise to determine the different types of soil. Briefly describe the main types of soil (sand, clay, silt and loam) and their properties. Divide the group into smaller groups of 3 to 5 persons each. Each group should run the test on at least two different soils, following the procedure described below in Guide to soil texture by feel. (A high-resolution version of the graphic can be downloaded at http://soils.usda.gov/education/resources/lessons/texture/soil_texture_hi.jpg)

Figure 1. Guide to soil texture by feel



Lesson 6. Soil fertility and nutrients

In this lesson you will learn:

- What are nutrients and which nutrients are most important for plant growth.
- About the two main types of fertilizers and the various application techniques for commercial fertilizer.

Plants need five things to grow – energy from the sun, water, air to breathe, nutrients from the soil, and a gas called carbon dioxide from the air. When a crop grows, it takes nutrients from the soil. If the nutrients are not replaced – by adding organic matter or commercial fertilizer – the soil becomes infertile and cannot produce future crops.

Also, each type of crop needs a different mix of nutrients. For example, maize needs different nutrients in different amounts than beans or cassava. And each soil contains different types and amounts of nutrients. Farmers with the best yields often know what nutrients their soils have, how much of which nutrients each crop needs, and when and where to add nutrients.

Box 3. Remember to put back what you take out!

If we keep taking nutrients out of the soil by cropping – but do not put any nutrients back into the soil – all of the nutrients in the soil will get used up and the soil will not give a good crop anymore. You can leave plant residue (stalks, stems and leaves) on the soil after harvest and during the dry season. Just before the rainy season begins, cut up this dead plant residue with a machete or hoe into smaller pieces. Leave it on the surface as mulch to keep the soil moist or mix the dead plant matter into the topsoil with manure. The soil animals will break it down into rich organic matter and replace the key nutrients in the soil. You can also replace lost nutrients by applying the appropriate types of commercial fertilizer.

Nutrients

To grow plants we need 17 nutrients. Three of these are very important and are needed in large amounts: nitrogen, phosphorus, and potassium, refer to as N-P-K. These are part of a group called macronutrients, used by plants in large quantities. Water and carbon dioxide provide carbon, hydrogen, and oxygen - the only three macronutrients required by all plants. Other macronutrients include calcium, magnesium, and sulfur. Below are some additional characteristics about NPK nutrients.

Nitrogen (N). Plants that receive plenty of nitrogen grow large and their leaves are dark green. Some plants (beans, clover or groundnuts) can take nitrogen from the air and, with the help of soil bacteria, produce nitrogen in the soil for other plants to use. These plants are called legumes. Animal manure and commercial nitrogen fertilizer also put nitrogen back into the soil.

Phosphorus (P). This nutrient helps roots to grow and flowers and seeds to develop. It can be added to plants as commercial fertilizer, or through organic matter and manure. It needs to be worked into the soil near plant roots because it does not travel with water down into the soil, as do nitrogen and potassium. The phosphorus content of the soil is reduced either by removing the crops or as part of soil erosion.

Potassium (K). This nutrient helps strengthen the stalks and stems, and it helps plants resist disease and drought. Like nitrogen, potassium can be washed away by heavy rains, flowing away with the groundwater.

In addition to macronutrients, plants also need smaller quantities of other nutrients. These are called micronutrients and there are eight of them: boron, chlorine, copper, iron, manganese, molybdenum, zinc, and nickel.

Because both macro and micronutrients have unique interactions with the soil, they need to be applied differently. For example, nitrogen may be applied on the soil surface if rains are near (called "top dressing"). Otherwise it should be mixed into the soil to keep it from evaporating. Phosphorus needs to be applied near the roots, because it does not move down into the soil with the groundwater

Using fertilizers

Maintaining the balance of nutrients in the soil over time is usually done through fertilizer. It replaces in the soil the nutrients that were used by the previous crop. Commercial fertilizers are expensive in terms of money. Fertilizers produced on the farm – such as compost, vermiculture (worm compost), animal manure, or green manure – are less expensive, but require more time and labor. Many small farmers use commercial fertilizers in small amounts when they can afford it and depend more on organic fertilizers that they produce on the farm. **Commercial fertilizers** are called **inorganic** because they are taken from minerals and ores. **Farm-made fertilizers** are considered **organic** because they come from plants and animals.

Commercial (inorganic) fertilizers

There are two main types of inorganic or mineral fertilizers. **Straight fertilizers** have one main plant nutrient, such as a nitrate or phosphate fertilizer. **Compound fertilizers** have at least two nutrients in different amounts. A common compound fertilizer is N-P-K fertilizer. Applying commercial fertilizer is tricky. Too much will "burn" or kill plants and pollute nearby water bodies, while too little will result in low yields.

Labels on fertilizer bags usually show the percent of N-P-K. For example, a bag of 7-14-7 means that the fertilizer contains 7% of nitrogen, 14% of phosphate and 7% of potassium. Most bags also have written instructions for handling and storage. Fertilizers can be dangerous to humans and animals if not stored and applied properly.

Box 4. Know your fertilizer needs

In many Zimbabwe soils, farmers need to add nitrogen and phosphorus for their maize crops, but not potassium. So buying a complete N-P-K fertilizer would be a waste of money and might reduce yields rather than increase them. In Nicaragua, many soils have enough phosphorus that is easily accessible. The application of N-P-K fertilizer to these soils – which was common practice in the past – actually resulted in chronic low yields, lower profits and water pollution.

Before considering commercial fertilizer carefully investigate the specific nutrient needs of the crop you will grow and the availability and nutrient composition of the soil. Soil tests will show what nutrients your soil lacks. These tests can be administered by a field technician or other agriculture experts/extension workers active in your area. You may have to pay for these tests yourselves, but it is possible to pool resources together as a group.

How and when to apply commercial fertilizer

- **Basal application.** Mix fertilizer into the soil at the base of the plant, often right before or after planting. Farmers often use compound fertilizers for basal applications. If your soil lacks phosphorus, it is especially important to apply it at planting time. Phosphorus speeds up root growth, and strong root growth helps plants to find the water and nutrients they need. Apply phosphorus in the soil at a depth where roots will be able to reach it. Phosphorus does not move through the soil and stays near where you place it.

- **Top dressing application**. The fertilizer is spread evenly over the field and applied on top of the soil after seeds become plants and while the crop is growing. Top dressing is often used for crops that are grown very close together and densely, and when the crop has roots that spread widely. For crops growing in wide rows top dressing is often applied on the soil surface, to the side of the row. Nitrogen and potassium are most often applied in this way. If they are applied before the plant has roots, water can wash these nutrients – especially nitrogen – into and through the soil before the plant is able to capture and use them. Also if nitrogen sits on the surface of the soil for a day or more it can evaporate. Wait until rainfall is moderate and constant before you apply nitrogen fertilizer.

- **Split applications.** This is simply top dressing in smaller amounts at different times while the crop is growing. With this application, fewer nutrients are lost and you can apply the nutrients when the crop needs them the most. If the soil is sandy, you need to apply fertilizer in split applications because sandy soils drain easily, and the water can sweep the nutrients away. If a soil has more clay, you can apply fertilizer less frequently.

Where to apply fertilizer

- **Banding.** Apply the fertilizer in a band in the soil beside the row of plants. The plants will take up more nutrients compared to broadcasting, and you will use less fertilizer. However, if applied too close to young roots, it can burn them.

- **Side dressing.** Use this method when the plants are up out of the ground and growing. Scatter dry fertilizer on one or both sides of a row, about 15-20 cm from the plants, and then mix the fertilizer into the soil.
- **Foliar applications.** Dissolve the fertilizer in water to make a weak solution and apply with a sprayer to the leaves of the plant. If the solution is too strong (too much fertilizer and too little water), it will burn the plant leaves. Foliar spraying is used for applying nitrogen as urea fertilizer and for some micronutrients. Do not apply foliar sprays when it is windy.

Conclusion

In this lesson we reviewed nutrients and their role in soil fertility. We described the main nutrients needed for a healthy crop - nitrogen, phosphorus, and potassium - and discussed other macro and micronutrients. We also talked about the main differences between organic and inorganic fertilizers. The last section describes basic principles about how and where to apply inorganic fertilizer

In the next lesson, we'll shift our attention to plants and what they need to grow healthy.

Quiz 6. Soil fertility, soil nutrients and nutrient cycles

See Annex 1 for answers.

True or False:

a. Plants need 5 things to grow: sunlight, air, nutrients, water and carbon dioxide.

b. Plants need 20 different types of nutrients in order to grow properly.

c. If you grow crops continuously on a field without returning any organic matter or nutrients, the nutrients in the soil will get depleted and eventually nothing will grow well on that soil.

d. The 3 nutrients that plants need in largest volumes are nitrogen, phosphorus and calcium.

e. Fertilizers can be either organic or inorganic.

f. All fertilizers have the same nutrients in them.

g. Organic fertilizers can be made on the farm.

h. The label on a bag of fertilizer only shows the percent of nitrogen in that fertilizer.

i. There is only one correct way to apply all fertilizers.

j. It is often better to apply different nutrients in different ways because they move differently in soil and water.

Field exercise 6a: Using fertilizers

Objective:

After this exercise the participants will be able to:

- Interpret the label on a bag of commercial fertilizer and to apply that type of fertilizer correctly.

Equipment needed:

- One label from a bag of commercial fertilizer, preferably one commonly available in the area.

Expected output:

- Group members practice "reading" the label of a bag of fertilizer and consolidate their knowledge on how to apply different types of fertilizers.

Time:

20 to 30 minutes

Preparation:

The facilitator should obtain a label from a locally-available commercial fertilizer and bring it to the meeting (if possible bring several labels from different fertilizers). The facilitator should also remind farmers about the different ways to apply different types of fertilizers before the exercise begins.

Suggested procedure:

1. Identify a volunteer from among the group who is willing and able to read the label. He or she should read the label aloud for the group.
2. Lead a discussion about the content of the fertilizer. Ask:
    - What does the label say about nutrient content and volume of the fertilizer?
    - What other types of fertilizer have you seen or used?
3. Once the group has correctly identified the contents of the fertilizer, lead a discussion on the different ways in which that fertilizer could be applied, and the pros and cons of each method. The group should then discuss and decide on the most practical and effective way(s) for them to apply that particular fertilizer. If interested the group can also discuss the application of other fertilizers.

Lesson 7. Plant health

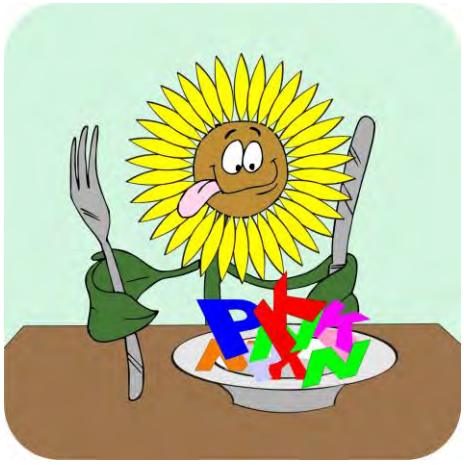
In this lesson you will learn:

- What plants need to grow and thrive (nutrients, air, water, light and soil)
- More about nutrients and the challenge of securing sufficient amounts of nutrients
- The threats posed by pests and disease

Plant nutrient needs

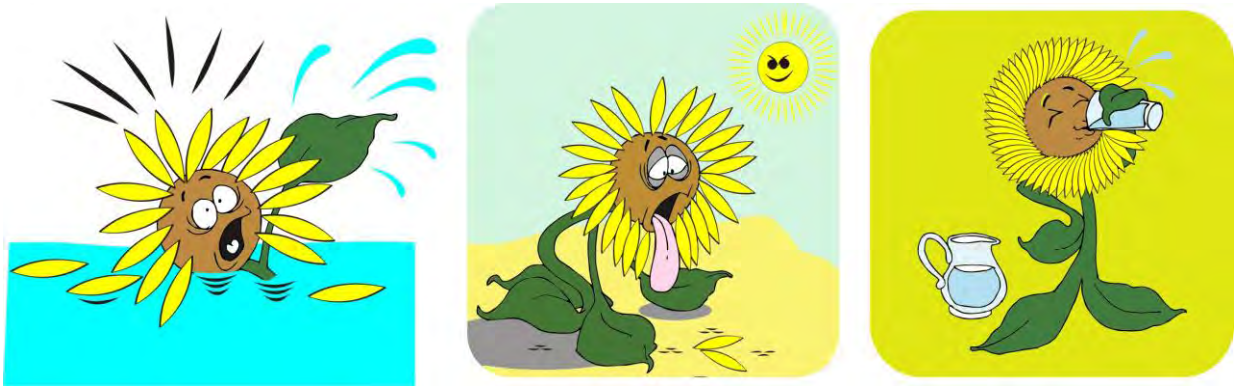
As mentioned in lesson 6, in addition to the three main nutrients – nitrogen, phosphorus and potassium – plants also need large amounts of the following nutrients: carbon, hydrogen, oxygen, sulfur, calcium and magnesium, and small amounts of other nutrients: boron, chlorine, copper, iodine, iron and zinc.

Several other concepts are important for plant nutrition:



- **Most limiting nutrient.** If the plant can access several key nutrients but is missing one (for example, it has nitrogen and potassium but not enough phosphorus) it will not give good crops. When enough phosphorus has been added, plant growth will be limited by the next "least available" nutrient. Limited growth will persist until all nutrients needs of the plant are met.
- **Nutrient movement.** Nutrients move in cycles. They move from the soil to plants and then to the animals that eat these plants. They move from the fertilizer that the farmer applies into the soil and then into the plants. The nutrients move off the farm when the farmer sells the harvest at the market. Also erosion takes nutrients out of the farm.
- **Nutrient deficiency.** When nutrients are lacking in the soil, crop growth is slow and plants are weak until the balance of nutrients is restored. The signs of nutrient deficiency are often very visible: short weak stalks, leaves that are spotted or a different color, and many others.
- **Nutrient sources.** These include commercial fertilizer, organic fertilizers (like animal manure, green manure, legumes, cover crops, mulch compost) as well as other intervention options (like crop rotation).
- **Soil pH.** This is a scale that measures the acidic or alkaline properties of the soil. Most plants do best in close to neutral pH (7.0), with an acceptable range between 6.0 and 7.5. Highly acidic (low pH) or alkaline soil (high pH) prevents certain nutrients in the soil from reaching the plants. For example, because acidic soils tie up phosphorus, plants cannot access it. Lime has to be added to these soils (to raise the pH) or there should be heavier phosphorus applications near plant roots. When soil pH is too high, it can be reduced by applying sulfur and/or some specific types of commercial fertilizer.

- **Nutrient availability.** Plants use nutrients in certain forms and not in others. For example, most plants cannot use the form of nitrogen that exists in the air.



Each plant has specific water needs, but usually access to moderate amounts of water is essential.

Plant water needs

Too much or too little rain for too long easily destroys plants. Especially when they are young, plants need moderate amounts of water. Young plants lack the network of roots needed for retrieving water deep from the ground. Consistent access to water is important for young seedlings and for crucial growth stages. In addition, plants need soils that are moist in order to access some nutrients, for example nitrogen and potassium. Having regular access to **moderate amounts of water** is essential for healthy plant growth. With too much rain the soil cannot provide sufficient volume of air; the roots will rot and the whole plant will die. If there is too little rain, plants cannot access the nutrients in the soil and the nutrients cannot travel through the plant. Plants wilt to prevent water loss from their leaves, and if the dry spell lasts too long they will die. Farmers around the world have found clever ways to conserve scarce water and drain excess water. (Zai holes and crops planted on ridges are two examples.)

Plant light needs

Plants need energy from the sun to grow. They transform light energy into **chemical energy**. Once plants have captured energy in this way, it can be utilized by all animals that eat plants. However, different crops need different amounts of light and different total hours of light (or darkness) in a single day. Maize, beans and potatoes all require high levels of light to grow well, while onions, carrots, and spinach require less light. There are also differences in desired day length. In order to flower and produce fruit or grain, many plants need a certain number of hours of darkness. Other plants will flower regardless of how many hours of light or darkness they receive. Some vegetables (lettuce, beets and spinach) flower only when they receive more than 12 hours of sunlight.

Plant soil needs

As mentioned in the previous lesson, plants need soil for several reasons. The soil provides a place for the plant roots to "anchor" the plant and hold it in place so that it can grow properly. Plant roots feed the plant by absorbing water and nutrients from the soil. The roots also need air, which they extract from the soil. If the soil is completely full of water, the roots cannot breathe well or function properly. Some crops (like rice) extract oxygen from the water, and thus do not suffer from this problem. Also, if soils are polluted (for example, by oil or car fuels seeping into the soil) plants do not grow very well and may even become sick.

Air

Like humans, plants breathe air. They take in oxygen through their leaves and roots, giving out carbon dioxide. Without oxygen, plants will die. Plants are also affected by air pollution, for example by a factory's discharge of dust into the air, or dusty rural roads. The small particles can settle on plant leaves and make it impossible to absorb sunlight, thus reducing their productivity. In some cases air pollution may be directly harmful to plants (sulfur and other pollution).

Pests and diseases

Like people, plants are affected by many different pests and diseases. Pests may include insects of various kinds, or larger animals like rats or rabbits that like a particular kind of plant.

Diseases also come in many forms. They may be viruses or bacteria, or many other types of micro-organisms that hinder plant growth and development. When large land areas are planted with a single crop (for example, maize planted on every farm across whole districts or provinces), the pests and diseases that prefer that particular crop have a favorable environment in which to grow and multiply. Outbreaks of pest or disease spread very quickly across these large areas and cause a great deal of damage.

An example is the Cassava Mosaic Virus. This disease has caused so much damage in Africa that some countries can hardly grow the crop at all anymore. A good way to reduce the probability of these kinds of outbreaks is to plant diverse crops on the same field, rotate the type of crop grown on a specific piece of land from year to year, and protect the diversity of species in your environment. For example, if certain kinds of birds are protected, they may eat some types of insects that might otherwise spread disease. The birds can help keep the disease in check. Promoting diversity of crops and other plants as well as diversity of animal and insect species helps maintain nature's balance and prevents major pest and disease outbreaks.

Conclusion

In this lesson, we begin by explaining additional principles about nutrients and their interaction with plants. We covered issues such as nutrient sources, movement, and deficiencies. We then discussed the specific water, sunlight, soil, and air needs of plants to give us healthy crops. We end the lesson by discussing how pests and diseases pose serious threats to our crops, and some ways to prevent and minimize their damage.

In the next lesson we introduce the concept of ecosystem.

Quiz 7. Plant health

See Annex 1 for answers.

1. The "most limiting nutrient" for plant growth is:

a. Nitrogen

b. Phosphorus

c. The nutrient that is the main cause of poor plant growth at any given time

d. A major nutrient that can be replaced with commercial fertilizer

2. Which of the following are sources of plant nutrients?

a. Commercial fertilizers

b. Water

c. Sunlight

d. Mulch

e. All of the above

f. Only a and d

3. True or False:

a. Plants can never have enough water.

b. All plants need the same amount of sunlight in order to grow properly.

c. Plants need to breathe air, just like people.

d. Plants can get sick, just like people.

4. Ways to minimize pest and disease outbreaks on a farm include:

a. Rotate the crops grown in any one field from year to year

b. Grow a range of different crops on the same farm

c. Protect the diversity of species in your local environment

d. All of the above

Field exercise 7a: Local plant health

Objective:

After this exercise the participants will be able to:

- Explain key concepts behind plant health in the local context.

Equipment needed:

- Flip chart and marker pens
- Samples of unhealthy plant material

Expected output:

- Group members have identified some of the key issues related to plant health in their community and shared ideas about how to address problems.

Time required:

30 to 45 minutes

Preparation:

Immediately before the group meeting, the facilitator should collect examples of unhealthy plants (these are plants that are suffering from either nutrient stress or pest or disease attack).

Suggested procedure:

1. Show the different samples of unhealthy plant materials to the group. Ask:
   - Have you seen such examples on your own farms?
   - Do you know what is causing the problem?
2. Continue by facilitating a discussion on plant health. Have group members identify the most important and common plant health issues locally. Explore examples from all areas relevant for plant growth: plant nutrition; too much or too little water; the effect of growing field crops in the shade (sun); the different soils and which plants grow well in the area; as well as pests and diseases (focusing on the most harmful).
3. After identifying the necessary elements for healthy plant growth, help participants identify the causes of several key problems that affect local crops. Continue by discuss various ways how these problems are being addressed and whether other strategies can be pursued. Ask the group to consider testing some of the practices recommended in this lesson to see if the situation improves.

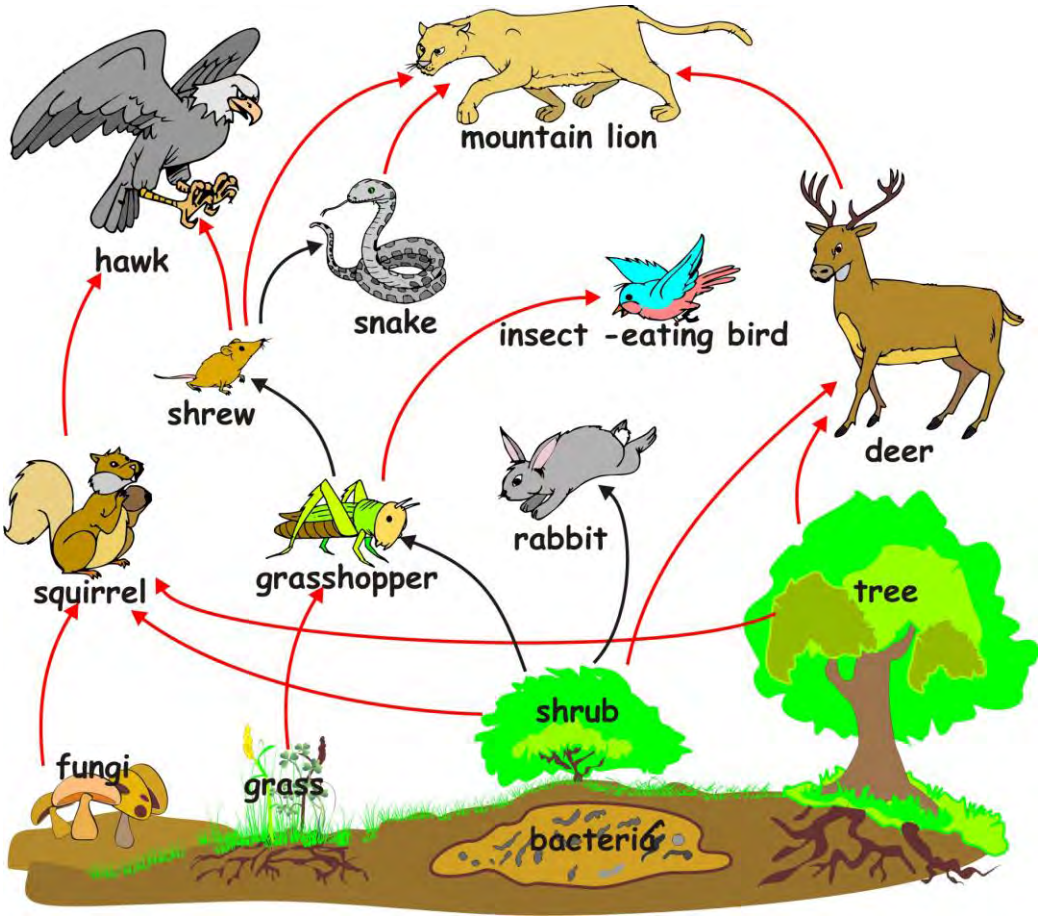
Lesson 8. Life systems in nature (ecosystems)

In this lesson you will learn:

- How all living things are connected in food webs and ecosystems
- About the different roles that "producers" and "consumers" play in food webs
- About the importance of maintaining diversity for healthy ecosystems

All living organisms (plants and animals) and non-living things (air, water, sun, soil) taken together make up an **ecosystem** – in other words, everything that we see and don't see around us. We are also a part of this environment, and our actions affect how it functions. In this system all living things are dependent and connected to one another. They continually exchange the nutrients and energy essential for supporting life.

Plants can do something animals cannot. Plants, through a process called photosynthesis, can produce **chemical energy** from sunlight,. This is why they are called **producers**. Animals that eat only plants to get energy are called **primary consumers** (e.g., cows). Other animals primarily eat other animals to get energy (e.g., wild cats mainly eat birds, mice and other small animals). These animals are called **secondary consumers**. Finally, there are animals that eat both plants and other animals. Humans are a good example of these **omnivores**.



When growing, plants also take up minerals from the soil and the air to make **organic matter** (the matter that makes up a living thing). When plants are eaten, some of their matter is absorbed and utilized by the organism that has eaten it. The same thing happens when an animal eats another animal. So when one organism eats another, both energy and matter are transferred from one to the other. A **food web** diagram shows the flow of energy and matter from producers to primary consumers, and from primary consumers to secondary consumers. When things die without being eaten, their matter usually is absorbed in the soil where it feeds plants, and the cycle starts again.

What is happening in the food web

Producers capture solar energy and convert it into chemical energy through photosynthesis. They also take up nutrients from the soil and the air, and combine them to make different kinds of organic matter. Energy and matter are passed from the producers up along the food chain from one organism to another. The number and types of organisms in the ecosystem depend on non-living factors (soil, water, temperature and light) and the interaction between the organisms. Removal of one or more species (or group of species) from an ecosystem has life changing effects on many others species. Removal of many species from an ecosystem will often result in loss of energy and matter, and severely reduced productivity of the system as a whole.

Broken food webs

Why is our field swamped with insect pests?

If we cut down most of the trees (for example, to make charcoal for sale in towns) the birds will not have a place to make their nests or to sleep in safety away from predators. They will settle elsewhere, and with a lot less birds around to eat insects, the population of insects will explode. With more insects eating our crops, our crop yields will go down.

Why are there more mice and rats in our storage bins?

Wild cats and snakes eat rats. If we kill all the wild cats and snakes the number of mice and rats will increase a lot, and they will eat much more of our stored grain.

All organisms are connected. We depended on our environment for survival.

Managing healthy ecosystems

As consumers, our lives depend on maintaining the productivity of our environment – both the non-living parts and all living creatures. If we do not manage it well, it can become less productive and our livelihood may be threatened.

Maintaining a **balance of species** in our environment can prevent problems related to booming populations of species (for example, having too many insect pests or rats). In unbalanced ecosystems the existence of many life forms is under threat. Increasing and protecting the diversity of living creatures in our environment (plants, animals and other living things) usually increases the productivity of our environment. A diverse environment provides multiple sources of vital energy and nutrients. It is home to more organisms and therefore also provides more economic opportunities. Also, having more diversity in predator organisms in the environment improves pest control. Having a lot of diversity in the environment increases our livelihood options and also helps us harvest healthier grains by decreasing the need for chemical control of insects and other pests.

Manage your resources carefully. Do not use them all up!

If we allow our soil and water resources to become degraded, we reduce our capacity to generate food and income as well as endanger the livelihoods of future generations. As the human population grows, we are using more resources at a faster rate. It is expected that it will continue to grow at an even quicker rate in the near future. It is very important that we manage resources well so that we do not destroy our own environment and our own livelihoods. The next lesson will provide some ecologically sound principles for farming and managing our local natural resources.

Conclusion

Lesson eight introduced the concept of ecosystem and how it's made of living organisms (plants and animals) and non-living things (air, water, sun, soil). Nutrients and energy have the ability to flow among all these elements to sustain life through a process called 'food web'. Knowing the dynamics of food webs can help farmers understand how to better deal with pest and diseases. Because broken food webs can alter the balance of our ecosystems and severely affect our livelihoods, we must manage our natural resources sustainably.
In lesson nine, the last in this manual, we'll bring all the concepts together and present you to the idea of sustainability.

Quiz 8. Life systems in nature (ecosystems)

See Annex 1 for answers.

1. True or False:

a. Our ecosystem is made up of all living and non-living things around us.

b. All living things in an ecosystem are connected in one way or another.

c. We are not part of any ecosystem.

d. In a food web, matter and energy are continually being transferred between organisms.

e. In a food web, some consumers only eat other consumers.

2. Which of the following are "primary consumers" (select all that apply)?

a. Rabbits

b. Mice

c. Hawks

d. Cats

e. Chickens

3. What will happen if all of the secondary consumers are removed from an environment?

a. The number of primary consumers will expand very rapidly.

b. The primary consumers will immediately die as well.

c. The biological diversity of the environment will be reduced.

d. Only a and c

e. All of the above

4. It is important to maintain diversity and balance in nature because:

a. It looks nice and feels good.

b. This will help prevent major pest and disease outbreaks.

c. It will help maintain energy and matter in our ecosystems, making them more productive and sustainable.

d. It is easy to do.

Field exercise8a: Introduction to food webs

Objectives:

After this exercise the participants will be able to:

- Describe how all living things are connected and the mechanism behind this connection.
- Explain the importance of biological diversity and maintaining balance in our environment.

Equipment needed:

- A large picture of a food web diagram. If there is none available then draw one using available tools (markers and paper, sticks and the ground etc.).

Expected outputs:

- Group members understand the roles of "producer" and "consumer" organisms as well as how matter and energy are transferred from one species in the food chain/web to another.
- Group member understand how the removal of one species affects the population(s) of other species and the need for balance in the ecosystem.

Time:

One hour

Preparation:

Familiarize yourself with the concepts of food webs, producer, consumer and their connections. Select some good local examples of the negative effects when the local ecosystem has gotten out of balance. Talk to the participants and the local inhabitants to explore these stories.

Suggested procedure:

1. Show the diagram to the group and ask group members to name local examples of some of the key species within the diagram (e.g., types of trees or grasses, types of insects, birds and other animals that eat those insects, local predators like wild cats etc.)
2. Explain how "producer" organisms use photosynthesis to convert nutrients and solar energy into organic matter and chemical energy. Also, explain how energy and matter are transferred from one organism to the next up the food chains.

3. Discuss with the group what happens when one organism (or animal) is removed from the web. What happens to the organisms to which it is connected?
4. Continue with a discussion on what is happening to the different groups or organisms in the local ecosystem. Use the following questions to simulate discussion. Please adapt the questions below and introduce other relevant questions if necessary:
    - Are there still many apex predators around (wild cats, tigers)?
    - Are the local producer organisms thriving (trees, grass)?
    - How are the current conditions of local producer organism, and what is the effect on the other species in the system?
    - Is there an increased number of insect pests in our crops? If so, why?
    - Are there more mice and rats in the storage bins? If so, why?
    - Why might it be bad to cut down all of the trees and make charcoal?
    - Where does the mountain lion get energy and nutrients, and what happens to the energy and nutrients in the mountain lion when it dies?
5. Summarize the main points from the food web diagram. Make sure that the following information is contained. All living things are connected to other living things (we are also part of this web). Chemical energy and organic matter are generated by producer organisms and move from one organism to another up the food chains. If one species of organism is removed from an ecosystem, it will have a serious impact on the other organisms. It is vital to protect the non-living resources that are necessary for producers to grow and prosper. They are the basis that supports all the other life forms in an ecosystem. Diversity and balance are important for the long-term productivity of the ecosystem.

Lesson 9. Sustainable use of natural resources – bringing it all together

In this lesson you will learn:

- About the consequences of environmental degradation and good practices of preventing and combating environmental degradation.
- About the basics of land use management.
- About ecosystem services and the steps taken to preserve these functions.
- About climate change and the effects of global warming.

Maintaining and increasing productivity

The lessons of this course clearly show that we need to very carefully manage our existing soil, water, and other natural resources. Good natural resource management in the long term will increase our capacity to provide food and secure income, thus building rich resources that we can pass on to our children.

Consequences of environmental degradation

We must not allow our **soil, water and other natural resources** to become polluted and degraded. It could seriously threaten our capacity to generate food and income. We may even have to leave farming altogether and look for work elsewhere, like in a nearby city.

If we allow the **diversity of our local natural resources** to degrade, it will have similar effects. The capacity to withstand adverse events (like droughts, floods or insect plagues) will be reduced. It will be more difficult to produce our crops. It will be difficult to get other resources from nature – like wild foods, medicinal herbs, and even firewood and building materials.

Lastly, as the **number of people in our area grows**, we will need to extract more from our natural environment. If we do not put a good management system in place, it is likely that we will use up or destroy all of the local natural resources very quickly. The result is the same – our livelihood will be threatened.

Box 5. Questions to think about in our community

Which important natural resources are being lost most quickly?

What will be the consequences to individuals, families and our community if these trends continue?

What are the local natural resources in our community that need to be protected right away?

Are there any concrete steps we can take right now?

Good practices for farming and natural resource management

- **Protect the soil at all costs.** Keep it covered as much as possible; minimize tilling and exposing the soil to the weather; build up the organic matter in the soil; and "put back whatever you take out" in terms of soil nutrients by adding either organic or inorganic types of fertilizer.
- **Capture and use rainfall.** Capture as much of the rainwater as possible, either in the soil (through infiltration) or in small dams. Use it carefully not wastefully.
- **All excess water should "walk, not run" off the slope.** This will prevent erosion by ensuring excess water does not carry away the topsoil. Use various tools (such as contour ditches and dams) to catch and channel this excess water safely down the slope.
- **Maintain a wide diversity of living organisms.** Only cut down trees that must be removed (both within your fields and in common-use areas). Only clear grass and weeds from areas where it is absolutely necessary. Do not burn crop residues or pasture lands. Do not over-graze common-use areas, as they may become bare and lose their topsoil. Remember that all living things are connected and that maintaining balance is the goal. Diversify your farming system by using different kinds of crops, trees, animals, and other income sources. This will provide stable production, a very valuable asset in times of uncertainty or poor harvests. In the same way, diversifying your local natural resources will also help make the environment more resilient.

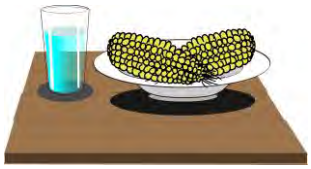
Basics of land use management

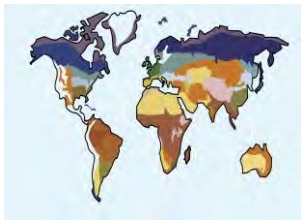
- **Steep slopes should be covered by trees and grass at all times**. You may have to build contour trenches on very steep slopes to protect the lower parts of the slope, usually several trenches at regular intervals.

- **Prevent erosion across the entire watershed** – both in crop fields and in common-use areas. This may require a number of technical solutions: keeping the soil covered with living plants or mulch; setting up contour trenches and/or live barriers; plugging gullies, and managing streams with small dams.
- **Make sure that excess water moves slowly** from higher to lower parts of the watershed. Water should "walk, not run" down the slopes.
- **Rainfall is precious – utilize and manage it carefully**. Capture as much rainfall in the soil as possible. After the soil is full, capture the excess water in small dams or infiltration pits. This water can be used either for crop or livestock production, or in homes for drinking and washing.
- **Ensure that runoff from our land does not carry pollution downstream**. Prevent agricultural chemicals or fecal matter (from people or animals) from entering the water. This will help ensure that the water leaving our community is clean and safe for those communities downstream.
- **Do not build homes or plant fields in areas prone to flooding** (unless the crop can withstand flooding). It is best to keep these areas covered with trees and grass. They can provide common-use areas for grazing livestock or for forestry-related activities.

Ecosystem services

Our environment provides various "services" that all people need (e.g., clean, safe water and clean air). The United Nations has identified four main types of these "ecosystem services":





- **Provisioning** – providing water and food of all living organisms.
- **Regulating** – maintaining stable microclimates across the globe, which determine the types of flora and fauna that can thrive there. Looking at threats to agricultural yields, this affects the spread of pests and diseases. For example, mosquitoes cannot survive in higher microclimates (it is too cold), and thus there are no mosquito transmitted diseases at these elevations. However, if some areas warm up considerably (due to global warming), mosquito populations may increase and bring the accompanying diseases.
- **Supporting** – cycling of nutrients and pollination of both crops and wild plants by bees and other insects. Pollination is vital for providing good yields for many key crops, such as fruit trees (avocados and mangoes), many vegetable crops, and field crops (sunflower and most legumes, such as beans, soybeans, cowpeas, pigeon peas etc.).
- **Cultural** – providing rural and wilderness areas that we use for spiritual and recreational purposes.

All people – regardless if they live in cities or in rural areas – require ecosystem services to survive. Ecosystem services provide food, clean water and clean air, which are essential for life everywhere. This is why people in urban areas have a responsibility to contribute to ensuring that ecosystem services function well. There are many locations on the planet where clean water is becoming scarce. In other locations deforestation is so massive that it is changing the local climate. As our population grows across the globe, maintaining ecosystem services will become more and more important. But, at the same time, it will be increasingly difficult to protect them. For this reason some governments are considering paying local communities to protect vital natural resources, thus protecting these services. This idea is called **payment for ecosystem services**.

What is climate change

There is substantial scientific evidence that the earth is slowly getting warmer, a process called **climate change** or **global warming**. Think about what happens in a greenhouse: the sun heats up the air inside, the air cannot escape and gets even hotter. Therefore, the temperature inside the greenhouse is much higher than the temperature outside. The same process is happening in the atmosphere. Gases known as **greenhouse gases** trap the sun rays, which heat up the earth even more. Carbon dioxide is the main greenhouse gas. It is released into the atmosphere through the burning of **fossil fuels**: coal, oil and gas. Burning trees or charcoal also releases a lot of carbon dioxide. As growing trees and plants absorb carbon dioxide, preserving plant life is the best strategy for reducing the amount of this greenhouse gas in the air and slowing global warming. In rural areas, reduction of plant life (deforestation or land burning) and loss of organic matter in the soil (poor planting practices) are often the biggest contributors to global warming.

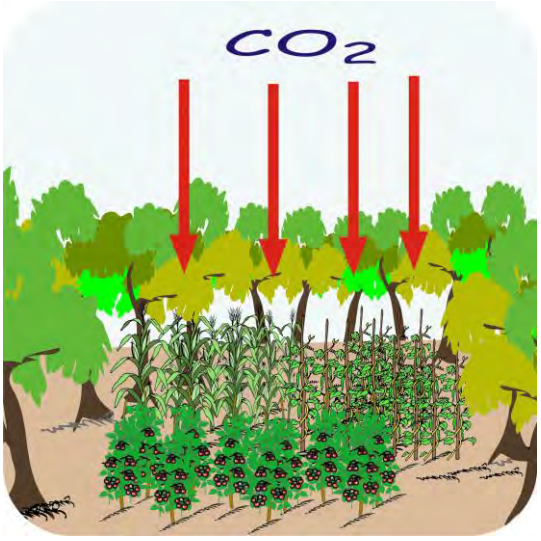
Effects of global warming

Global warming has many adverse effects that seriously threaten the wellbeing of our planet. Higher temperatures can lead to wells and streams drying up. Due to lower temperatures certain crops will not be able to grow at the same altitudes anymore. For some farmers, climate change may bring unpredictable and heavier rains, while for others it could mean more frequent and severe droughts. These impacts are varied across the globe, but there are several broadly documented effects:

- **Desertification.** Increases in land areas that are deserts, arid or semi-arid.
- **Loss of agricultural land.** Due to expanding deserts or new flood plains.
- **Altered patterns of crop or livestock.** Certain varieties or species adapt better to changing temperature conditions, others cannot adapt and perish or migrate.
- **Altered patterns of pests and diseases**. Some pests adapt better to changing temperature conditions and new pests can emerge in some areas. Existing pest management may not be effective against these new pests.
- **Flooding of coastal areas.** Caused by rise in sea levels due to the melting of the polar ice caps, it can result in loss of habitat and livelihood.
- **Migration.** Worsening of livelihood or living conditions may drive some people to migrate from areas significantly affected by climate change. If substantial, this migration flow may increase population pressures, especially in cities.

Not all the effects of climate change are negative. Temperatures changes may create optimal environments for maize or other crops to grow in new areas, thus providing new livelihood opportunities. Some crops may experience longer growing seasons, actually improving the food security in the area. Still, climate change is overwhelming seen as a serious threat to life on earth.

Farmers and climate change



Farmers everywhere can contribute to reducing the effect of climate change by taking steps to absorb more of the carbon dioxide from the atmosphere. Primarily this means increasing plant growth (by reversing deforestation and reducing burning) and increasing the content of organic matter in the soil (through sustainable farming practices). If the effects of climate changes start to have a severe impact on livelihoods, farmers can take a number of actions. They can change the types of crops grown or livestock raised. They can build or improve irrigation systems. They can plant trees and use cover crops to increase the number of growing trees and plants. Also steps to improve the content of organic matter in the soil, like no-tillage farming, can be taken.

Protecting resources and livelihoods for future generations

To use resources sustainably does not only mean managing resources well today, so that we and our children enjoy healthy, prosperous lives. It is to think about future generations, so that our children's children and their children will also enjoy a productive and healthy environment.

We should develop management plans – for our own land but also for the broader community – that will maintain and increase the productivity of our local natural resources. We need to teach our children to do the same. This course has provided you with the knowledge and basic technical approaches for protecting your local natural resources. But **it is up to you** and your

community to expand and apply this knowledge and **develop your own systems** for protecting and nourishing your local natural resources.

In a way, we received these natural resources as a gift from our ancestors and our parents. These resources do not belong to us. We are the current "caretakers" of these resources, and we should use them responsibly and wisely while we struggle to build happy, healthy and productive lives. But it is also our duty to pass them on in good condition to the next generation, so that they may enjoy the same prosperity. We must teach our children to follow our example and to use responsibly and preserve these natural resources for future generations.

Conclusion

This last lesson introduces the idea of sustainability and the important of managing our natural resource in a way that accounts for future generations. We discussed good farming practices from previous lessons that help us manage our resources better. Similarly, we listed the key principles of land use management and gave you some ideas on how to make them happen. We then described the various services that ecosystems can offer, such as provision, regulating, supporting, and cultural. As a major threat to these services, we mentioned climate change and its impact on desertification, loss of agricultural land, flooding, and other changes to our ecosystem. We finished this lesson by reminding you about the important caretaker role you have in protecting our natural resources for ourselves and our future generations

Quiz 9. Sustainable use – bringing it all together

See Annex 1 for answers.

1. Why is it important to manage soil, water and other natural resources?

a. To protect our ability to produce food and income

b. To protect vital ecosystem services

c. To ensure we pass on to our children rich, productive natural resources

d. All of the above

2. Which of the following are good farming practices?

a. "Put back what you take out" to manage soil fertility

b. Make sure that excess water "walks" off of the field and does not "run"

c. Grow only one crop to maximize production

d. Keep your soil bare to maximize rainwater infiltration

e. Only a and b

f. Only a, b and d

3. What are some key "ecosystem services" that our natural environment provides?

a. Clean water for drinking and other uses

b. Food to eat

c. Clean air to breathe

d. All of the above

e. None of the above

4. What is climate change?

a. When it rains in some months and not in others

b. When it is hotter in some months and colder in others

c. The earth's atmosphere is slowly getting hotter due to an increasing amount of greenhouse gasses in the air.

d. Only a and b

Field exercise 9a: Ecosystem services

Objective:

After this exercise the participants will be able to:

- Explain the concept of "ecosystem services" in their local context.
- Describe the concept of "payment for ecosystem services" in case it is offered by external agencies.

Equipment needed:

- Flip chart, marker pens.

Expected outputs:

- Group members have identified the main ecosystem services that they enjoy in their local environment.
- Group members have discussed the payment for ecosystem services model and have identified such opportunities (if available).

Time:

45 minutes to one hour

Preparation:

Familiarize yourself with the concept of ecosystem services. Identify at least one locally specific ecosystem service in each category (provisioning, regulating, supporting and cultural). The facilitator should also review the concept of payment for ecosystem services and examine whether any organizations are supporting this scheme in the community or wider area. Consider inviting representatives of these organizations to this meeting.

Suggested procedure:

1. Present to the group the concepts of ecosystem services and payment for ecosystem services. Ask if there are any questions, and lead a short discussion to clarify these concepts.
2. Guide the group in a discussion of local examples of ecosystem service. Cover each of the four categories (provisioning, regulating, supporting and cultural); list as many examples as possible on the flipchart.

3. Ask the group who – outside of their community – also depends on these services that are generated in their community. For example, clean water and clean air might be used by people in nearby urban centers. Write down as many as the group can list. Discuss whether these external people should have some responsibility for maintaining the ecosystem services that they depend on.
4. Ask the group how the negative environmental trends they identified earlier in their ecosystem assessment might impact local ecosystem services and the people identified in point 3 above. Discuss the concept of payment for ecosystem services. If there are examples of local initiatives in the area discuss these in great detail, covering the organizations, the types of services and implementation. If there are no suitable local examples use examples from the region or country.
5. Continue with a discussion that will examine the benefits and weaknesses of the scheme. If there is a locally available initiative consider inviting a representative of the organization to the meeting. Ask multiple questions to better explain the scheme and its benefits as well as to assess local interest in participating.
    - Which key resources are preserved by the initiative?
    - How does the community benefit from safeguarding these resources?
    - Would their community be interested to participate in such a scheme?
    - Who might have an interest in making such payments?
    - How would these payments be handled?
6. Record the answers and make sure that the group retains a copy for future reference.

Field exercise 9b: Protecting natural resources – today and for the centuries ahead

In this exercise, the group will review the importance of protecting natural resources, now and for future generations. They will also discuss some of the challenges and how to address them.

Objective:

After this exercise the participants will be able to:

- Identify the importance and benefits of protecting their natural resources.
- Identify key constraints to sustainable natural resource management and actions to address them.

Equipment needed

- Flip chart, marker pens, printout of **Figure 2. Two scenarios for the future**.

Expected outputs

- Group members have discussed and reviewed their own rationale for protecting their local natural resources.
- Group members have identified the key challenges they face in preserving their natural resources and some actions that can address these challenges.

Time

45 minutes to one hour

Preparation

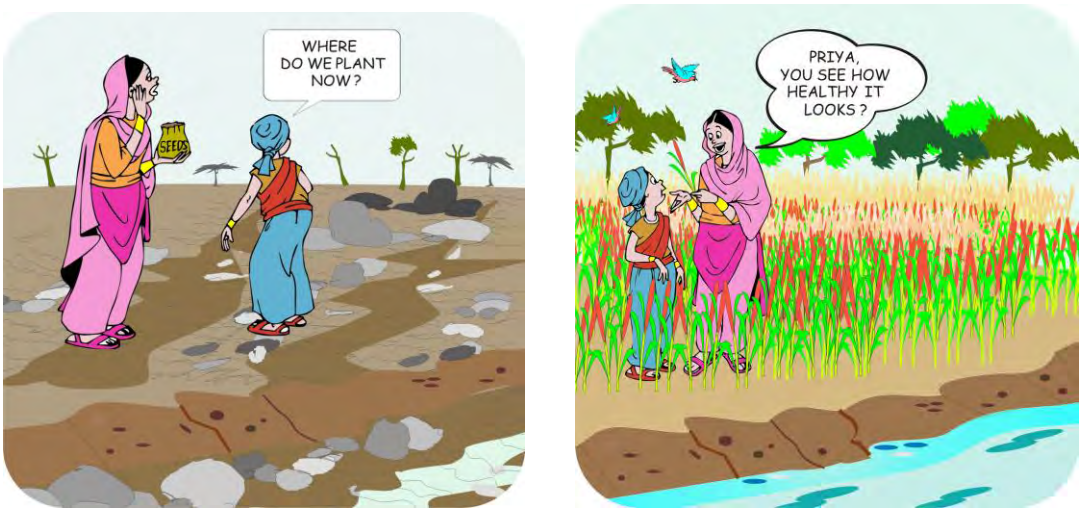
The facilitator should review the rationale for protecting local natural resources (livelihoods, ecosystem services, current trends with natural resources) and be prepared to lead the group in a discussion of this topic.

Suggested procedure

1. Start the meeting with a discussion on the local natural resources that are essential for their livelihood. Make sure that you cover various resources (soil, air, water etc.) and multiple sources (for example, a stream, a lake and rain as sources of water).
2. Once the main natural resources are identified, continue by facilitating a short discussion on the most important ecosystem services for the community (please cover examples from all four: provisioning, regulating, supporting and cultural).

3. Bring the two together by engaging the participants to talk about the current trends with key local natural resources.
   - Are most of the natural resources healthy and being managed well?
   - Are any particular resources under threat, and how serious is the situation?

Figure 2. Two scenarios for the future



4. Pass around the two pictures from **Figure 2. Two scenarios for the future** and ask which scenario is more likely to occur in their community. Recap the key local natural resources and trends. Lead the group in a discussion of what specific developments could lead to the outcome in each picture. Use the key trends identified during the previous discussion as starting points. For example, if there was a problem with erosion caused by gullies, lead a discussion into what would happen if the gullies expanded and the erosion got worse. Conversely, discuss what will happen if they are plugged/filled and contour lines are constructed on the slopes.
5. Continue by exploring the challenges to addressing these problems. Ask the group to identify some key constraints. Write down the key constraints on the flipchart, relating them to type of ecosystem service and type of problem (erosion etc.). Specify the problem and solutions:
   - What actions could they take to address these constraints?
   - Who could take this actions, and in which timeframe?

   Write down all answers on the flipchart, to preserve a record for the community.
6. At the end of the discussion, thank the group for their inputs and encourage them to both implement what they have learned and to share their knowledge with others in their community and beyond.

Resource materials

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Useful Websites:

www.crs.org (look under: about us: publications: agriculture)

http://ga.water .usgs.gov/edu (on the water cycle and related topics)

http://www.mysciencebox.org (useful information on ecology, food webs, and other natural systems)

Annex 1. Answers to quizzes

Answers to Quiz 1:

1: C. All the things that we take and use from nature are "natural resources."

2: B. Renewable resources are natural resources that replenish themselves. They are very valuable – if managed correctly we can enjoy these resources for a very long time.

3: C. Generating sustainable livelihoods assures the long-term prosperity of our families.

Answers to Quiz 2:

1: D. Water is not created or destroyed; it moves in a continuous cycle. Once it is on the ground it can flow on the surface, sink into the ground or evaporate into the sky.

2: D. For plants to use water adequately, the water needs to slowly seep into the soil and stay in the ground as much as possible. Excess water should gently flow off the field.

3: A. Water flowing quickly over unprotected land can cause serious damage to the topsoil.

4: E. Soil erosion is a serious problem that can threaten the health and livelihood of entire communities.

Answers to Quiz 3:

1: E. Water should be captured and retained in the soil so that plants can absorb it. When water drains it should exit the fields slowly and safely, so as not to cause erosion.

2: E. Especially on sloped land it is important to reduce the risks of erosion, by covering the land, planting trees and other plant growth with strong roots, and also making contour trenches across the slope when appropriate.

3: A – True. Soils that contain more organic matter retain water longer.

B – True. Stopping soil erosion preserves the topsoil, which retains water that plants can use.

C – True. Mulch acts as an organic soil cover, keeping moisture in the soil.

Answers to Quiz 4:

1: C. All areas – even if they are very flat – are part of a watershed.

2: False. Effective water management depends on cooperation.

3: D. Identifying early signs of problems is particularly important. Especially early detection of erosion helps prevent bigger damage to the land.

4: E. Explore and share good water mangemement practices with your field agents and community.

5: False. When using water always consider how it impacts those who use it after you.

Answers to Quiz 5:

1: D. The soil fulfills multiple functions for plants; it provides air, water and nutrients; it anchors the plant's roots making them more stable etc.

2: A – False. Most nutrients are found in the topsoil.

B – False. It takes centuries to replace one centimeter of topsoil.

C – True. All living organism can turn into organic matter.

D – True. That is where the organic matter is found that plants can use.

E – False. On the contrary, organic matter is essential for life.

3: D. Regularly adding organic matter to the soil keeps it fertile.

4: A – False. The three main textures of soil are sand, silt and clay.

B – False. Loamy soils are a mix of sand, silt and clay. All soils have organic matter in them.

Answers to Quiz 6:

A. True. All five are necessary; even if only one thing is missing the plant will not grow properly and may even die.

B. False. Plants need 17 nutrients, of which three are most important: potassium, nitrogen and phosphorus.

C. True. Nutrients need to be regularly replenished or yields will suffer.

D. False. Nitrogen, phosphorus and potassium are needed in the largest volumes.

E. True. Organic fertilizer is cheaper as you can make it on the farm from residual organic matter.

F. False. The most commonly used fertilizer is N-P-K, but there are other fertilizers that have one or two of these nutrients, and others that have additional nutrients.

G. True. They can be made by you on your farm; this makes organic fertilizers cheaper and more readily accessible.

H. False. The label shows all the nutrients, application instructions and key precautions for handling the fertilizer.

I. False. There are many different ways to apply fertilizer, depending on the type of fertilizer, the type of crop and how it is planted, the time of year and other factors.

J. True. Indeed different nutrients should be applied differently. For example, phosphorus should be applied near the roots of the plant as it does not travel down into the soil with water.

Answers to Quiz 7:

1: C. If one of the three main nutrients is missing, it can seriously endanger the health and even the survival of the plant.

2: F. There are many natural sources of nutrients to explore.

3: A – False. Plants – just like people – can also drown in too much water because they can't breathe.

B – False. Light needs vary greatly for different plants.

C – True. Yes they need oxygen just like people.

D – True. Plants are very vulnerable to disease when grown in monocultures.

4: D. Depending on the major pests and diseases in your area, there are many different strategies that you can explore.

Answers to Quiz 8:

1: A – True. All life forms in the ecosystem and all non-living things make up an ecosystem.

B – True. Even if only one living thing is taken out it disturbs the entire ecosystem.

C – False. As a living thing humans are also a part of the ecosystems where they live and travel. What we do has a significant impact on the ecosystem.

D – True. Matter and energy are continuously moving from one living thing to the next.

E – True. These so-called secondary consumers do not consume producers but only primary consumers.

2: A and B. Primary consumers only eat producers (plants).

3: D. The number of primary consumers will increase and many will die or leave the ecosystem, as there will not be enough food to support their increased population. This could also have a serious effect on the producer population if it is also decimated by too many primary consumers feeding on it.

4: C. Maintaining this balance is not always easy; however, it is essential for the long-term wellbeing of all life forms in the ecosystem.

Answers to Quiz 9:

1: D. We do not own our natural resources; we are borrowing them from our children's children.

2: E. Good farming practices can greatly improve the fertility of the soil and the yields.

3: D. We receive four key ecosystem services: provisioning, regulating, supporting and cultural.

4: C. Climate change is a very serious problem that threatens our livelihood and even life on the planet as we know it. Especially coastal areas are at greatest risk.