Where There is No Farm Advisor

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an ECHO® Release

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Introduction

In the present global climate of food shortages and price increases in food and fuel, it is more important than ever that communities improve local, sustainable food production. This handbook is a preliminary resource to introduce to you methods and concepts in tropical agriculture, and to assist you in conducting further research. Feel free to contact me (Robin Denney) with any questions at: redenney@gmail.com. Also be sure to look through the Resources section of this booklet for further research and assistance.

Using this Handbook

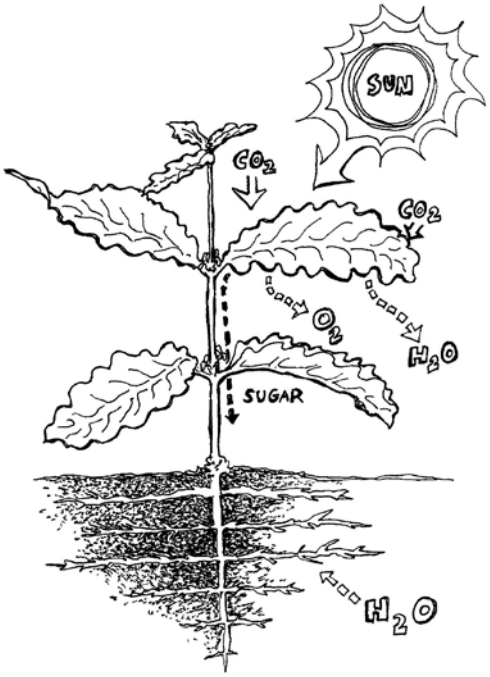
- Use **Plant Biology for Beginners**, or **Animal Science for Beginners**, to get a basic knowledge of the science behind caring for plants and animals.
- Use **Working in Local Communities**, for suggestions and cautions when beginning and conducting your work in agriculture with local people (especially if you are not working in your home region).
- Then, with the help of local farmers, learn as much as you can about the situation, problems, and farming practices in the area (read **Assessing Agriculture Production** and **Assessing Livestock Production** to learn some techniques).
- When you understand the problems, use Addressing Problems, for suggestions in improved techniques.
- Use the **Resources** section to assist you in conducting further research specific to the concerns of your region, including expert advice, free handbooks for download, and tropical agriculture online libraries. Publications by ECHO and Agrodok are mentioned throughout the text. Instructions on obtaining these publications can be found under **Resources**.
- Start a small garden, so that you can try some of these techniques (see **Demonstration/Teaching Garden**).
- The symbol : 🌍, indicates ideas particularly favored by the author.

Plant Biology for Beginners

What Do Plants Need?

Sunlight, water, minerals, carbon dioxide, oxygen, and something to grow in or on, usually soil or another plant.

How does Photosynthesis work?



Photosynthesis is a metabolic pathway that takes water, carbon dioxide from the air, and sun energy to produce sugars and oxygen.

$$(H_2O + CO_2 + \text{sun energy} = C_6H_{12}O_6\,(\text{sugar}) + O_2)$$

Plants' leaves and green stems contain chlorophyll, a pigment that absorbs energy from sunlight. The plant temporarily stores this energy chemically, like a battery, in two molecules called ATP and NADPH. ATP carries this chemical energy around the cell, and gives it up to be used in different processes that require energy. In the second phase of photosynthesis, ATP and NADPH are used in a reaction which takes carbon dioxide and water and makes sugar and oxygen. (If you look at the chemical formula, you can see how this is possible as the molecules are broken down and rearranged.) Oxygen is released from the plant, and the sugar is sent throughout the plant, where it is consumed as a source of energy and used as a building block for protein and other essential chemicals in the plant. It is stored for later use in stems and roots as carbohydrate (starches). Sugars stacked and bound together form carbohydrates and cellulose. Cellulose is the basic component of fiber that gives structural strength to the plant and is the source of fiber in the human diet.

What can farmers learn from this?

Most plants need maximum access to sunlight to grow best in temperate climates. In the tropics and subtropics where the sun is at times directly overhead, the light may be so intense that for some plants, like many temperate vegetables, partial shade can be helpful. Plants receiving too much shade will soak up less sun energy, and therefore not grow as well. (Exception: some plants, especially trees, need shade while they are seedlings. Some plants like coffee and heat sensitive vegetables like cabbage and collards may grow better in partial shade.)

What do leaves do?

Leaves are where photosynthesis occurs. They also sweat (in plants it is called transpiring). The leaves give off water, and as the water evaporates the plant is cooled. Leaves have tiny holes on the underside, which allow oxygen and water to escape, and carbon dioxide to enter. These holes are called stomata, and they can open and close. When they open, water evaporates from the interior of the leaf. If the plant is under water stress during the heat of the day the stomata will remain closed, because the plant knows it cannot afford to lose more water. When the stomata stay closed, photosynthesis stops, because carbon dioxide cannot enter the leaf and oxygen cannot escape (exception: succulent plants like cactus and pineapple avoid water loss by only opening stomata at night and storing carbon dioxide chemically so it can be used for photosynthesis when the stomata are closed).

What can farmers learn from this?

When a plant is under heat stress, its leaves and growing stem tips will begin to droop. If this is happening, then photosynthesis and plant growth have stopped. The plant needs water, and possibly some shade to correct the situation and continue growing. Water stress can become severe enough to kill the plant. This will begin with the oldest leaves falling off, and the growing stem tips will dry up and die back. Crops differ in how much water they transpire. Those that transpire a lot will require more rainfall or irrigation.

What do roots do?

Roots collect water and send it to the leaves for photosynthesis and transpiration. Roots also take up nutrients, which are critical for photosynthesis and for growth. The most important nutrients for plants are nitrogen (N), phosphorous (P), and potassium (K). Nitrogen is critically important, because both chlorophyll and amino acids (amino acids make up proteins) require nitrogen. Symptoms that show nitrogen is lacking include the yellowing of leaves, reduced growth, and lower yield. Many other minor nutrients are necessary in small amounts. Some symptoms indicating that nutrients are lacking include deformity in growth, spots on leaves, and die back. (Note: these can also be symptoms of disease or pests).

What can farmers learn from this?

It is critical that farmers care about the health of the soil. With each crop, nutrients are removed from the field at harvest. If no new nutrients are added (through fertilizer, mulch, manure, etc.), the next harvest will be smaller.

How do branches form?

A growing shoot tip (end of a stem) produces a hormone called auxin which moves down the plant and stops the buds on the stem from growing into branches. The further it has to travel the less effective it is at this, so branches begin to form. If you pinch off the shoot tip of a plant, you remove the hormones, and branches will begin to grow. Once auxin gets down to the roots it acts as a root growth hormone. The roots produce an opposite hormone called cytokinin. As cytokinin travels up the roots it suppresses root growth. When it gets to the branches, it encourages new shoots to grow. In this way, the plant is able to keep its root growth and shoot growth in perfect balance. If many shoots are trimmed or eaten, then the plant has more cytokinin than auxin, so it produces more shoots. If roots are broken off during transplanting, there is more auxin, so more roots grow.

What can farmers learn from this?

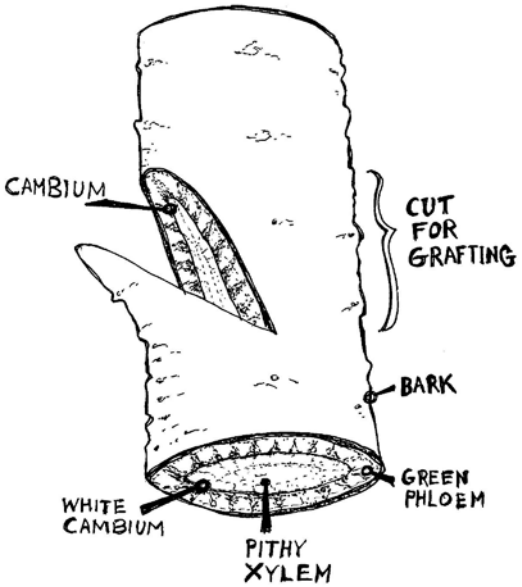
Pruning encourages branching by reducing the amount of auxin that inhibits branching. This is especially effective when plants are younger, and is important on trees that are used to produce food. More branches lower down means better access to fruits, nuts, and leaves. Also, when transplanting, trimming back the shoots will help remove some stress from the plant, since roots will be broken during transplanting.

What are Xylem and Phloem?

Xylem is the plant tissue that carries water up the plant. It is made up of specialized plant cells that die after they are formed, leaving an empty tube that acts like a drinking straw. As water is used for photosynthesis and transpiration in the leaves, more water is drawn up through the xylem to the leaves. Xylem is located at the center of stems. In trees, the active xylem is the outer ring of the woody interior (the older wood is xylem that is no longer in use).

Phloem is the green layer just under the bark. Phloem is formed from living cells on the outer rim of a stem. Phloem moves the sugars formed in photosynthesis down the plant to be used for growth or stored in the roots, stems, or fruits. As phloem dies, it becomes bark.

The layer of cells between the xylem and phloem is called the cambium. The cambium layer produces new xylem cells on one side, and new phloem on the other. It is white and smooth and can be seen if you slice into a stem with a knife (the xylem is usually white and pithy on the other side). If the cambium layer is damaged, it takes a long time to repair. (Think about a large tree branch that is pruned. With time, what appears to be bark swells up around the wound, until after many years the bark touches again, and the cambium layer re-connects.)



What can farmers learn from this?

Girdling (cutting around the outside of a stem with something sharp, or slowly strangling with a string or vine) will kill a plant. If you want to graft a plant, the cambium layer of your improved variety MUST touch the cambium layer of your original plant. If the wound is sealed, the two cambium layers will knit together, and the bud or stem that was added will grow. When tapping a tree (as for rubber production), be careful not to cut too deep and damage the cambium layer, or the tree will drop in production.

Animal Science for Beginners

What do Livestock need?

Water, air, food, exercise, light, and, in some cases, protection from the elements.

What can livestock keepers learn from this?

It is the responsibility of the livestock keeper to see that the animal's needs are being met. The attentive keeper can tell if animals' health is improving or declining. Without enough water, the animal stops eating and stops growing. Daylight contributes to vitamins in the body, but too much sunlight can overheat livestock. Keepers should experiment with increasing the quality or quantity of the feed if the animals are performing poorly.

What is the life cycle and production cycle?

The important events in an animal's life cycle are: birth, weaning, growth, and either slaughter or breeding and birthing. Milk and eggs are produced in cycles. For example, a dairy cow's production cycle is 10 months of milking followed by 2 months to dry up in preparation for birthing. Hens lay eggs for a period of one year then go through a molting period where they do not lay, before returning to laying.

What can livestock keepers learn from this?

The weight, overall health, and productivity of the animal at each stage in its life or production cycle is an indication of the quality of the animal. Keeping records of this information will tell you which are the best animals in the herd. You can use this information to improve your herd or flock through selective breeding (see page 33).

What are the facts about breeding?

In most livestock the female goes through an estrous cycle, which takes an average of 21 days. During this time the uterus (womb) is prepared to receive a pregnancy, and an egg is released into the womb. The period of time when the egg is released is referred to as "heat" or estrus. When a female animal is in heat, her behavior changes, and there are certain physical signs that show she is in heat. Heat lasts for one to three days, and for most livestock this is the only time when the female will be receptive to the male mounting her. (Rabbits are the exception; the release of the egg is stimulated by breeding.) Also see Table 1, page 6, for the age of different livestock at maturity, and the length of time for pregnancy (gestation period).

What can livestock keepers learn from this?

By watching their animals for signs of heat, and by keeping records, keepers can plan the pregnancies of their female animals, decide which males they want to mate to them, and thus improve their herd over time (see selective breeding, page 33)

What should I know about genetics?

The quality of the animal, their potential for growth and productivity, their resistance to disease, and their ability to survive on scarce food during the dry season, are largely determined by genetics. Genes are passed from parents to offspring. Two very poor quality livestock parents will not produce high quality offspring. However, one poor quality animal and one better quality animal can produce improved offspring.

What can livestock keepers learn from this?

Selecting a breeding pair where one has good traits in an area where the other is lacking, could result in improved offspring. Over several generations, the herd will improve dramatically (see selective breeding, page 33).

What do I need to know about digestion?

Animals need a source of energy, protein, and fiber. Energy is used in exercise, work, milk or egg production, and growth. Protein is used for growth and milk or egg production. Fiber is used in the digestive process and in ruminant animals is digested for energy and protein. Different species require different kinds of food based on their digestive system.

Ruminants: Goats, sheep, cattle, buffalo, llamas, and camels are ruminants. They have four stomachs, and they cough up their food and chew it again which is called chewing their cud. Ruminants have microorganisms in their first stomach that digest cellulose (which otherwise could not be digested by animals).

What can livestock keepers learn from this?

Ruminants are an excellent choice for an area where there is a lot of plant life that cannot be used by humans, or areas of land that cannot be used for farming. Ruminants can survive the dry season on very poor quality feed (see *Agrodok 7, Goat Keeping in the Tropics*, Resources page 41).

Monogastric: Pigs and poultry have one stomach. Monogastric animals require high quality feed, with plenty of protein (see Feed and Water page 32).

What can livestock keepers learn from this?

Monogastric animals are useful in an area where there is often a crop surplus that goes to waste. Pigs should not be free to wander wherever they wish, because they spread diseases to humans. Before deciding to raise pigs, carefully evaluate whether you will be able to sell them for an amount greater than the investment in feed that you will have to make. Poultry that wander freely, or that are kept in a large fenced area will feed on insects and weed seeds, and so can be a useful part of the family garden. Poultry raised in a cage or house must be fed high quality feed, and are more susceptible to disease and injury.

Hindgut fermenters and pseudo-ruminants: Horses, mules, and donkeys are hindgut fermenters, meaning they have one stomach but are able to digest plant cellulose in their intestine with the help of microorganisms. However, they are not nearly as efficient at this as ruminants are. Rabbits are pseudo-ruminants. They have one stomach, but they digest their food twice by eating their feces. They are efficient digesters of cellulose.

What can livestock keepers learn from this?

Because horses, donkeys, and mules are not efficient in their digestion, they will need additional energy-rich feed in order to increase their ability to work. Rabbits are highly efficient and productive meat animals.

Table 1. Livestock breeding and digestion facts.

	Goat	Sheep	Cattle	Pig	Chicken	Horse / Donkey	Rabbit
Maturity	12–14 months	12–14 months	12–14 months	6–9 months	20 weeks	4 years	4–9 months
Estrous cycle	21 days	17 days	21 days	21 days	N/A	21 days	N/A
Gestation	5 months	5 months	8 months	115 days	N/A	11 months, horse 12 months, donkey	4 weeks
Digestion	Ruminant	Ruminant	Ruminant	Monogastric	Monogastric	Hindgut fermenter	Pseudo-ruminant
Signs of Heat*	Vocal, less appetite, more urinating, tail wagging	Friendliness to male	Agitated day before then stands for cows to mount	Stands when pressure applied to back	N/A	Urinates in the presence of male, winking vulva	N/A

*Heat is indicated by a friendliness to the male and by a swollen and red/dark pink vulva with clear discharge, in addition to the species-specific signs listed above.

Working in Local Communities

Subsistence and Commercial Agriculture

Subsistence agriculture, farming done by families on small plots to produce the bulk of what is consumed by the family, is the backbone of most developing agricultural economies. Being able to produce their own food supply gives subsistence farmers a level of stability by providing protection against job loss and fluctuations in the economy. Higher producing commercial agriculture is also important for national food security and economic gains, but should not be favored to the exclusion of subsistence agriculture. Improving subsistence farming to make it more sustainable is critical. Small improvements in efficiency and yield can help subsistence farmers increase their production and have excess crop to sell in the market. With extra income, farmers can continue to improve their agriculture practices and their quality of life (education and health). This bottom-up approach to agricultural development is different from the top-down "green revolution" model currently being promoted (which proposes to reduce hunger by increasing large-scale, chemical-dependent agriculture). Increasing country-wide food production does not mean the impoverished subsistence farmer will get to eat any of it. The family is not farming because there is no food, but because there is no money to buy food. Though both are important, I would argue that improving the lives of subsistence farmers reduces hunger and promotes stability and peace.

Sustainability

The concept of sustainability in agriculture means that farmers use a system of farming that will be able to sustain itself perpetually. When trying to develop sustainable systems, it is important to think locally, and also long-term. How can farmers produce the inputs they need locally (fertilizer, seed, tools)? How can farmers change their practices in order to increase the health of their soil, environment, and crop? What low-cost options are available?

Non-Sustainable Example: An example of short-term thinking is a system that encourages farmers to plant higher performing genetically modified or hybrid seeds. This may quickly solve the problem of low yields, but it can create a dependency on foreign-produced expensive seeds which require fossil fuels to transport and distribute. This system also replaces the locally produced seed. If something goes wrong with the imported varieties (e.g., bad taste, susceptibility to pests, lack of supply, poor nutritional value) the community may not be able to revert quickly to their old seed because supplies may be diminished or lost.

Sustainable Example: A sustainable system encourages local production of seed; low-cost fertilizing methods such as mulch, compost, and planting of legumes; and non-chemical pest management or natural pesticide recipes.

This booklet highlights potentially sustainable methods. Using the local knowledge of your community and region, you can determine which methods are truly sustainable in your region.

Respect

When working in local communities, whether you grew up there or you came from far away, it is important to show culturally appropriate respect to the people and elders of the community. It is also important that you go beyond the outward display of respect, and come to a place of feeling respect.

Showing Respect: When living in a new culture, learn the proper ways of showing respect. This can include (but is not limited to): how you dress; who you address first when asking a question; how long you wait in silence; how you greet a person; your tone of voice when speaking; whether to bring a gift; how to receive a gift; and whether it is appropriate for you to speak directly to someone of the opposite sex.

A visiting development worker listens to and learns from the local farm advisor in Abara, South Sudan.

Feeling Respect: Truly feeling respect for the ways of another culture means that you must let go of some attitudes you may not even know you have. Paternalism is one of these fatal attitudes. This is where you

feel you are coming from the “haves” to give to the “have-nots”. It is an outcome-oriented, charity-minded approach. This attitude blinds you from being able to see the wisdom and value of local ways, and it sets up an unhealthy one-sided relationship. Let go of paternalism as well as any prejudices or stereotypes you may hold. Approach a new culture with true respect, realizing your way is only “a way”, not “the way”. Open yourself to learn from the hundreds or thousands of years of wisdom and agricultural experience of your hosts. Help them to articulate and implement their own vision, rather than imposing a vision of your own.

Eagerly learning from local people is one of the greatest ways to show genuine respect for them. ECHO’s co-founder, Dr. Martin Price, tells of his first visit to subsistence farms in Haiti. He asked himself, “If my passport and cash were taken from me and I were given a small plot of land here, would I be able to survive?” His conclusion was that he would, but only by quickly making friends with local farmers who would be able to teach him how to farm under the unique difficult set of conditions in that particular part of the world. Later, because of his training and contacts, he would be able to help them go beyond local knowledge to evaluate new ideas that could potentially improve the productivity and profitability of their farms.

Patience

Don’t be hasty! Western/northern culture is fast-paced, and in entering the cultures of the global south, we must slow down. A slower pace of life is not backward, it is just different. You may even find that you prefer the slower pace and see its value, if you take the time and develop the patience to live it. You may be frustrated by what you perceive as a waste of time and an inefficient use of labor and resources, but you will not change the pace by being angry about it. Try to see what is good about this cultural difference.

Caution

Proceed CAUTIOUSLY with any change. Never make or encourage changes in farming systems that are irreversible.

For example, large-scale or free range cross breeding of local livestock with foreign livestock can weaken local livestock’s natural resistance to disease, and effectively wipe out local livestock production.ECHO was told of a well-intentioned project in a very remote South American community that brought in fast-growing, white chickens for better meat supply. Unfortunately, the introduced hens had lost the genetic disposition to set on their eggs long enough to hatch chicks. As the “improved” roosters bred with local hens, this trait was passed on to the general chicken population and soon the numbers of chickens declined. Reportedly people finally banned growing any white chicken.

As another example, large-scale replacement of local crops with higher producing foreign crops can wipe out seed stores and can prove disastrous if the higher producing seed must be purchased year after year, or if there is some problem related to its growth or use.

When trying to introduce new techniques for farming, try the new techniques on a small portion of a plot and compare the growth of the specially treated plants with the traditionally grown plants. Encourage farmers to experiment, but advise them to start with only a small portion of their crop.

Assessing Agriculture Production

Learning the History

Begin by asking questions of farmers:

- Is the community able to produce enough food to feed the population?
- Is malnourishment a problem in the community? If so, research more about malnutrition in health books, such as *Where there Is No Doctor* (Resources, page 41). Also see “Nutritional Problems,” page 36.
- Is the community mainly producing food for their own consumption? This is subsistence agriculture. Problems often include low yield, poor storage and preservation of food, pests, flood, drought, erosion, physical damage to crop (from a storm or during harvest), lack of availability of seed, not enough labor, high cost of tools, and access to land. Lack of income may also result in low education and poor health.
- *Or* Is the community mainly or partially producing crops to sell? Crops that are grown to be sold are called “cash crops.” Problems with cash crop production often include: low yield, pests, flood, drought, erosion, lack of labor, high cost of labor, access to land, lack of credit or money for crop inputs (fertilizer, chemicals, seed, tools, etc.), difficulties in transporting the crop to the buyer, distance to or lack of processing facilities, fluctuating market prices, and markets controlled by monopoly corporations.
- What do the farmers say are problems in crop production? Are the problems recent, or have they been present for a long time? How have they addressed the problems?

Assessing Plant Health

Look at the stems, leaves, and flowers; also examine the fruit (if present) or other edible part. Ask the farmer how the growth and current health of the plants compare to past crops, and to crops in other regions. Look for any of the following symptoms:

Low yield

Yield is the weight of crop harvested per area of land. Decreasing yield over time is a common problem, and can be caused by all of the factors described below.

Water stress

Look at the soil; is it dry? Look at the plants for the following signs of water stress:

Recent stress: limp and drooping or curling leaves, and drooping stem tips

Prolonged stress: Larger and older leaves fall off, stem tips dry up, leaves turn yellow, new leaves stay small.

Flooded

Is there standing water on top of the soil? In prolonged flooding conditions, most plant roots will suffer from lack of oxygen and will begin to rot. The plant will actually not be able to get enough water, even though water is everywhere. It will display the same symptoms as water stress. (Rice, taro, and other swamp plants are the exception to this rule).

Lack of nutrients

Some symptoms include: yellowing of leaves, other discoloration, slow growth, small leaves, flowers that set little or no fruit, deformity of stems or leaves, and discolored spots or dry spots on leaves.

Pests

Can you find any insects or eggs on the plant? Are there signs that insects are damaging the plant?

Common Insect Pests

Grasshopper/locust/katydid: Can cause major damage, usually you can see where they are eating leaves or fruit.

Caterpillars/moths: Eat leaves and fruit, sometimes curl leaves to form nests/cocoons.

Mites: Insects almost invisible to the naked eye, they cause tiny spots to form on the leaf where they feed.

Aphids: Small insects that feed off of the phloem, usually found on soft new stems.

Mealy Bugs: Also phloem feeders. They are white, and exude a sticky goo. Ants farm mealy bugs, because they eat the sugary goo exuded by the mealy bugs. Ants will care for the mealy bugs, and move them to new feeding locations.

Beetles: Some kinds of beetles eat plants, and other kinds hunt harmful insects. Observe the beetle in question to see which kind it is.

Nematodes: Microscopic worms in the soil that feed on roots. Check the roots for swellings and deformities, usually found on the small fibrous roots (exception: round white balls on the roots of legumes contain beneficial bacteria).

Wasps/Flies: Some kinds of wasps and flies harm plants or fruits, while other kinds hunt harmful insects. Observation is key.

Animals, Birds, Rodents

Livestock and wildlife can cause significant damage.

Disease

Fungus: Some kinds of fungus are parasitic and attack the plant for food. Fungi range in size from single cell organisms to large mushrooms. One kind of fungus is mildew, which often looks like powder or black spots on plants. Larger fungi include plant-like growths on the bark of a tree or stem of a plant. A fungus growing on the tip of a growing shoot can contort it. If only part of the plant is affected, prune that part and destroy it. If the whole plant is affected, see the next section on viruses.

Viruses: Viruses often cause plants to mutate; leaves curl strangely or get strange stripes, and shoot tips can contort and curl. Viruses are spread by growing new plants from infected plant material (stem cuttings). They are also spread from plant to plant by certain insects and nematodes. Plants cannot be cured of a virus; the plant must be destroyed to stop the virus from spreading. Viruses usually spread very slowly, and most often occur due to propagation. Be sure you know that cuttings used for propagation are from healthy plants.

Bacteria: Bacteria can take the form of rot on stems, roots, or leaves.

Assessing Soil Health

Slope: Does the land have a shallow or steep slope? Erosion may be a problem on slopes. Is the land flat, low, or near a river, and thus subject to flooding or to areas of standing water? It is helpful if you have an opportunity to see a field right after a heavy rain.

Soil profile: Dig a hole - the top layer of soil should be dark and loose. This is the topsoil where most of the nutrients are found. The subsoil should be lighter in color and more compact. How deep is the topsoil? The deeper it is, the better the plants will grow. If the topsoil is thin, see if there is soil erosion (If there is, see Erosion on page 23).

Soil Color: Dark soils are rich in decaying organic material, which is full of soil nutrients. Light colored soils can be lacking in nutrients. Red soil has a high content of iron. Iron does not harm the plants directly, but red soils tend to be dense and to form crusts, and thus can be difficult for roots to penetrate (Gibbon, 12).

Soil Texture: Soil texture affects the water holding capacity of soil. Soil is classified by its content of each of three sizes of soil particles: sand, silt, and clay. Soil that is a mixture of all three particle sizes is called loam soil. Loam soils are ideal because they combine good water-holding capacity with good drainage. Clay soils have excellent water-holding capacity but poor drainage. Sandy soils have excellent drainage, but poor water-holding capacity.

Soil Texture Test: Take a lump of soil in your hand and wet it. Sandy soil cannot be formed, even into a ball. Loam soil can be formed into a ball, or rolled into a cylinder shape. Clay soil can be rolled into a thin cylinder and bent into a U without cracking.

Soil Structure: For ideal soil structure, soils require decaying plant material. This is called organic material. It provides nutrients, but also gives a loose and spongy structure to the soil, which allows roots to penetrate easily and allows tubers (i.e., potatoes, cassava) to grow. Organic material also improves the water-holding capacity of sandier soils, and provides food to increase the population of helpful microorganisms in the soil. (See “Life Below the Surface” by Danny Blank, EDN 96).

See “Addressing Agricultural Problems: Yield,” on page 13 for information on soil-improving techniques.

Assessing Livestock Production

Learning the History

What is the productivity of the livestock?

Indicators include: number of offspring, successful pregnancies, live births, weight at weaning, and survival to maturity. In producing animals, look at liters of milk or number of eggs per day. In work animals, look at how much work they are able to do.

What livestock production system is being used?

- **Uncontrolled:** The livestock wander freely without supervision.
  - Problem: Theft, predators, injury, parasites, diseases, low productivity, high death rate.
  - Benefit: No cost in maintaining animals.
- **Semi-intensive:** The livestock are restrained with ropes or fences or are supervised.
  - Problem: Cost or time involved in keeping animals.
  - Benefit: Better protection of the animals. Productivity depends on the quality of care.
- **Intensive:** The livestock are confined in a building or small pen all the time.
  - Problem: Expensive to set up and maintain, all feed must be gathered and brought to the animals. Disease spreads quickly.
  - Benefit: Stops parasites, prevents animals from destroying crops, simplifies manure collection for use in making compost.

What are the causes of death (or loss) among the livestock? Disease, injury, strangling, poisonous plants, predators, theft, starvation, lack of water, parasites (such as ticks and worms), diarrhea.

What is the health history of the herd? How often are animals sick? With what kinds of illness or parasites? What treatment(s) is/are used? Do farmers have access to veterinarians or livestock health workers and to basic medicines?

Assessing the livestock

What is the general health of the livestock?

- **Body condition:** Are the livestock skinny? Fat? Do they have well defined muscle? (problems in this area can be caused by feed ration, disease, parasites, or too much or too little exercise)
- **Hair/feathers:** Are the hair/feathers in good condition and shiny, or dull and patchy? (Problems may be caused by feed ration or skin parasites.)
- **Injury:** Any open wounds or sores? (problems can result from an accident, poor livestock keeping, or too many animals in a small space)
- **Infestation:** Are there insects in hair/feathers, or worms in the dung?
- **Discharge:** Look at the nose, eyes, mouth, anus, and vulva or penis. Is there a liquid dripping out? What color is the liquid? (Colored discharges can be a sign of infection. Bloody discharges are a sign of more serious disease or internal problems).

Teams of oxen are frequently used to work the land and transport goods in Usulutan Province, El Salvador.

- **Skeletal structure:** Are the sizes of the head and the ribcage in proportion to the rest of the body? Do the legs or feet bump into each other when the animal walks? Is the animal pleasing in appearance? (Structural problems can result from poor genetics, injury, or poor feeding early in life).

The ideal livestock would have plenty of muscle and fat (though not too much fat); have shiny hair in good condition; be free of injury, disease, infestation, or colored/bloody discharges; and have a head and rib cage in proportion to the size of the body (the rib cage should be approximately half of the total height from the back down, in four-legged animals). When walking, the animal should be able to walk in a straight line without limping and without the legs or feet bumping into each other.

Addressing Problems

Agricultural Problems

Yield

Low yield occurs when a plant is not getting what it needs to grow. All of the plant and soil health problems listed on page 9 can cause a decline in yield. Look for suggestions below regarding the specific problems you find. However, your primary concern should be improving the quality of your soil to increase the nutrient and water-holding capacity, which will almost always translate to better yield.

Burning

"Slash and burn." Many farming systems use a process where land is cleared, the green material is burned, and then the crop is planted. The ash is a good source of phosphorus, potassium, and minor nutrients, sometimes resulting in lush growth in the short term. But burning vaporizes all of the nitrogen (which is the most important nutrient for growth). For a few years, the plants are able to get N from the rotting roots of the plants that were burned. After that, a sharp decline in yield requires the farmer to move to a new site. This system is only sustainable if the farmer has enough land to allow each site to lie fallow (i.e., unused, see page 16) for 7 to 20 years. Returning too soon to a site means the ability of the land to support growth steadily declines over time. This contributes to deforestation. If done throughout a region, the climate and rainfall can be affected.

Mulch

"Slash and mulch." This alternative to burning has many benefits–green material that is cleared from land is used as a mulch.

How to

Clear plant material from farmland, and lay it evenly across the ground or pile it around the individual crop plants. Do not mulch right up to the plant stems, as this may lead to rot and provide cover for certain insects to attack the stems. A deep mulch, six inches (15 cm) or so, is ideal for soil fertility, water retention, and weed control. However, locating and transporting that much mulch for field crops is unrealistic in most small-farm settings. Mulch of any depth will still reduce water evaporation and, to a lesser degree, erosion.

The layer of mulch closest to the soil will decay first. As it decays, the mulch will get thinner. Continue to add more mulch on top.

Mulching of tomato plants with grasses in Yei, South Sudan.

Benefits

- **Fertilization:** As the plant material decays, it releases nutrients into the soil.
- **Topsoil thickness:** As it decays, the mulch creates a nutrient rich organic layer to the topsoil, which thickens it.
- Soil structure: Mulch adds organic material to the soil, which improves aeration and water-holding capacity. Mulch also absorbs the impact of rainfall, preventing the formation of a thick crust on top of the soil and reducing erosion.
- **Soil moisture:** Mulch absorbs the heat from sunlight and shades the soil below, which helps keep moisture from evaporating.
- **Erosion prevention:** Rain hits the mulch and then slowly trickles down to the soil, giving it time to soak in. When the soil is saturated, the mesh of decaying plant material slows down run-off and helps prevent erosion.
- **Weed suppression:** A thick layer of mulch will block sunlight from reaching the soil surface, keeping weeds from sprouting.
- **Microorganisms and worms:** mulch encourages beneficial microorganisms and worms that add nutrients, make nutrients available, and aerate the soil.

Compost

Decomposed plant material and kitchen waste makes nutrient-rich compost, which can be added to the soil to improve nutrient content, soil structure, and soil life.

In-row basket composting for vegetable production, at the Crop Training Center in Yei, South Sudan

How to

It is good to use different types and textures of materials in a compost pile. Having both coarse dry material and green material is important. Manure adds nutrients, and topsoil provides the right micro-organisms.

Compost Pile: Make a pile, with alternating layers. Put coarse difficult-to-decompose material at the bottom. Then add layers of green material, manure, and a thin layer of topsoil. After 2-3 weeks, mix up the pile. Wet the coarser and drier material, and put it in the center of the pile as it is re-formed. Three weeks later mix the pile again. Mixing may need to be repeated a third time.

Compost Pit: Dig three pits, approximately 50 cm deep (18 inches). Follow the same order for layering as for the heap technique. The top layer should be soil or banana leaves to keep water from evaporating. After three weeks, mix the compost by putting it into the next pit (you can then put new composting materials in the first pit). Three weeks later, mix it and put it in the third pit. Three weeks after that, the compost should be ready to use.

Application: Apply compost around each plant, or dig a hole where each seed will be planted and fill it with compost. This will make your compost go further than just spreading it evenly across the soil.

(Information from *Agrodok 8, Preparation and Use of Compost*)

Benefits

- **Fertilizer:** Compost is rich in soil nutrients and helpful soil microorganisms.
- **Topsoil thickness:** Compost will thicken the topsoil.
- **Soil Structure:** Compost adds decomposing organic material to the soil, which improves aeration and water holding capacity.

Manure

Animal manure is full of plant nutrients, and can improve the health of the soil.

Caution

Adding raw manure directly to a plant can burn the plant. Also, manure should be handled and used with caution because it contains *E. coli* bacteria and other disease agents. Be especially careful using manure around leafy vegetables such as lettuce that are likely to be eaten without cooking. Raindrops can easily splash manure and disease organisms onto the leaves. In the United States, illness and death (resulting in massive recalls) have been caused by this. Do not use human feces, because it can spread deadly diseases.

How to

The best way to avoid the negative effects of manure is to compost it first. The heat of the composting process will kill bacteria. If you choose not to compost it, you should mix it with some dry material like straw, rice hulls, dry leaves and stems, or sawdust, which will make it less potent and less likely to burn the plants. Spread this mixture of manure and dry material around the plants, or dig a hole and place it in the hole with topsoil before you plant your seeds.

Benefits

- **Fertilizer:** Manure is rich in soil nutrients.
- **Topsoil thickness:** Manure will add to the topsoil.
- **Soil Structure:** Manure adds decomposing organic material to the soil, which improves aeration and water-holding capacity.

Green Manure

Green manure is a term for the use of nitrogen-rich plant material as a fertilizer, like manure.

Caution

Straw and similar brown plant material is low in nitrogen, as nitrogen has moved into the harvested seed or crop. Working large amounts of straw or brown plant material into the soil can have unintended consequences. Microorganisms in the soil multiply rapidly because of all the carbon in the plant material. But because the straw has little nitrogen, microbes get their nitrogen from whatever is in the soil. The result can be that roots of the newly planted crop will not find nitrogen. Leaves will suddenly turn yellow in color and the plants will give no or reduced yield. This is not likely to be a problem if the straw is used on top of the soil as a mulch.

Grasses tilled into the soil.

How to

Green manure is usually mixed into the soil. You can plant a cover crop of legumes (any bean plant). When it is time to prepare the field for planting, the cover crop can be tilled into the soil. You can do this with wild plants that are growing in the field, but be cautious if these are weeds, because tilling them under may cause them to spread. You can also use crop residues (but see caution above). Everything that is green has nitrogen in it, and you can capture that nitrogen in your soil by letting that green material decompose.

How is this different from mulching? Green manure is buried in the soil, similar to animal manure. Mulch is placed on top of the soil. Green manure puts nutrients into the soil more quickly than mulching, but the nutrients are also used up quickly as the decomposers in the soil break them down. Mulching has a longer-lasting effect. These two techniques can be used simultaneously so that you get the best of both!

Benefits

- **Fertilizer:** Green manure adds soil nutrients.
- **Topsoil thickness:** Green manure will add to the topsoil.
- **Soil Structure:** Green manure adds decomposing organic matter to the soil, improving aeration and water holding capacity.

Legumes, Cover Crops, and Crop Rotation

Legumes are plants that can take nitrogen from the air and put it into the soil. All beans are legumes. Other legumes include kudzu and clover, and trees like acacia, gliricidia, and leucaena. You can tell legumes by the tiny whitish round nodules attached to the roots. Nodules are pink on the inside if they are active. Nodules are home to beneficial bacteria which do the work of taking nitrogen from the air.

How to

Crop Rotation: You can rotate crops. This means you don't continue to plant the same crop on the same land. Instead, you switch crops each planting season, following crops that use a lot of nutrients (like corn and cassava) with legume crops (like beans or cowpea). This way the legume crops can replenish some of the soil nitrogen. However, most of the nutrients still leave the field when you harvest the crop, so you need to combine this technique with others.

Example: In El Salvador they plant corn at the beginning of the season. After harvest they leave the corn stalks standing, and plant beans, which climb on the stalks like a trellis.

Cover Crop: You can plant a legume that is not usually used for human food between your rows of food-producing plants. This is called a cover crop. (Some cover crops, such as lablab, do produce a bean that is a nutritious food for humans and animals.) It will cover the soil and act like a living mulch, having many of the same effects as mulch. If the cover crop starts to compete for light and water with your crop, you can slash it down, and use it as mulch. Or you can grow your cover crop seasonally and till it under as a green manure.

Caution

In dry climates, cover crops can compete with crop plants for scarce soil moisture.

Inter-Planting Crops: You can plant many crops together–for example, a row of beans next to a row of corn. The beans will help to nourish the corn.

Benefits

- **Fertilizer:** Legumes add nitrogen to the soil.
- **Erosion Prevention:** Cover crops help hold the soil in place and prevent erosion.
- **Weed Suppression:** Cover crops shade the soil and compete with weeds, effectively suppressing weed growth once the cover crop is fully established.

Fallow

This is what farmers call it when they leave a field to rest for a time. It is a very ancient technique, which is mentioned different times in the Old Testament of the Bible. Leaving land fallow allows some of the soil nutrients to be replenished, because wild plants grow and die and all of the nutrients remain on the farmland (nothing is harvested). A fallow period is also good when disease and pest pressure is high. Many pests and diseases of crops require those crops to be present in order for them to thrive. If the land is left fallow for a time, many pests and diseases die off.

How to

Leave the land alone for at least a year.

Fallow with Cover Crop: If you plan to come back to the land in a short time (one or two years), you do not want wild weeds to take over and leave their seeds behind. You can discourage this from happening by planting a cover crop of a legume plant. Do not mix it into the soil like you would with green manure. Just leave the cover crop, and let it take over for a year or two. When you come back to farm the land again, use the cover crop as a green manure or as a mulch, or as the bulk of a compost heap. Do not let all that good plant material go to waste!

Long-term Fallow: If the land has been farmed for many years, and you are having difficulty getting yield to improve even with other techniques, you may need to leave the land alone for 7 to 20 years. In that period of time, the forest or native ground cover will begin to re-grow and the land will recover. For a long-term fallow, you don't need to worry about weeds, just allow nature to do what it will.

Benefits

- **Soil nutrients:** The process of fallowing increases the quantity of nutrients in the soil.
- **Topsoil thickness:** The topsoil will thicken over a long fallow period.
- **Pests and diseases:** Fallow periods will cause pests and diseases of crop plants to die or leave the area. This is especially true of nematodes (microscopic worms that feed on crop roots), because many are crop specific. Leaving land fallow is the best way to deal with nematodes.

Alley farming

This is a system of farming where crops are planted in swaths (alleys) between hedgerows. The hedges are generally multi-purpose trees or leguminous shrubs. When the hedges get tall enough that they interfere with the crop for light, they are slashed down and the prunings are used for mulch (or livestock feed). The roots of the hedges grow deep into the soil, accessing nutrients that the crop plants cannot reach. These nutrients are put into the stems and leaves of the hedge plants, which are then used to nourish the crop (as mulch), or to feed livestock.

A pigeon pea hedge used for mulch production in an alley farming demonstration in Juba, South Sudan.

How to

Hedge row plant selection: Choose a hedge row that meets your specific needs. Look for a plant that is readily available locally. Good hedge plant traits include: deep rooted, leguminous, fast growing, edible to livestock, good for firewood, medicinal, source of human food. Avoid plants that are known to have roots that spread near the soil surface, because they can reduce yield of the alley crop.

Here are some common choices:

- Leucaena is a fast growing leguminous tree and probably the most popular hedgerow tree in alley farming.

- Gliricidia is also a leguminous tree. Its wood can be used for firewood, and its leaves can be used to feed livestock.
- Pigeon Pea is a leguminous shrub. The beans can be harvested for human food or pig feed, and the leaves can be fed to livestock or used as a mulch.
- Moringa is not a legume, but is very fast growing. Its leaves have exceptional qualities as human and livestock food and medicine, and also make a highly nutritious mulch. (see Moringa on page 36)

Plant Spacing: Hedgerows on flat land should be planted at least 5 meters (15 feet) apart, and parallel to each other. The spacing may have to be adjusted for your specific location. Plant hedgerows east-west so that the crops planted between the hedges will have maximum sun exposure.

Contour Planting: If you are putting alleys on sloping land, you should plant hedges along the contour of the hill to prevent erosion (See Contour Planting on page 23 for more detail). If planting on the contour, be aware that your rows will not be straight, and the distance between the rows will vary.

Pruning: Hedges should be pruned back severely as soon as they are competing with crop plants for water or light. They may need to be pruned more than once in the growing season. The prunings should be laid down as a thick mulch. You can also use the prunings to feed livestock, but if you do this remember that you are taking nitrogen and other nutrients out of the field, and you need a plan to replace that lost nitrogen (legumes, manure from the animals fed by the hedge, mulch, compost, etc.).

Alleys for Livestock: You can establish an alley system for livestock exclusively, or rotate grazing and crop growing. The hedges act as edible fencing. Between the hedges you have grazing space. The ends of the alleys can be blocked off, and you can practice rotational grazing to reduce parasites and improve pasture growth. The hedges can be cut for feed during the dry season when the grazing land is dry.

Benefits

- **Mulching:** Hedges provide a nutrient-rich mulch (see mulch benefits page 13)
- **Soil nutrients:** Deep-rooted legume hedges access nutrients deep in the soil and put nitrogen in the soil.
- **Slow the spread of pests:** Hedges form windbreaks that slow down the spread of pests on the wind.

Mixed Cropping

Mixed cropping is where you plant different types of crops together. You can choose crops that are beneficial to each other, like putting legumes alongside crops that use a lot of nutrients, or planting shade-producing shrubs or trees to shelter crops that require shade. You can also combine tree crops with row crops. In this way you produce different types of food for your household, and the different types of plants benefit each other.

How to

Tree orchards and row crops: When a tree crop is planted, it is generally spaced so that the trees form a solid canopy. In mixed cropping, you leave a little more space between the trees so that light can penetrate to the "understory." Choose crops that tolerate shade. Collards and cabbage grow well in partial shade, which protects them from wilting. Vanilla and coffee respond well to shade. Ask local farmers what else grows well in shade. Rotating legume crops or cover crops in the understory will help replenish nutrients and suppress weeds.

Legumes and row crops: Planting legumes alongside row crops (such as corn or cassava, which mine nutrients from the soil) will produce higher yields in the crop and will protect your soil from severe depletion of nutrients during the growing season.

Gardening: Many small subsistence farms are grown in a garden style, with different crops together in the same plot, sometimes planted at different times to stagger harvest dates.

Mixed cropping of maize and groundnut (peanut) in Yei, South Sudan. (Note the maize has too many plants per hole, and the rows are too far apart to allow for successful wind pollination.)

Benefits

- **Soil nutrients:** Combining legumes or tree crops with row crops increases the amount of nutrients available to the crops.
- **Pests and diseases:** Having different crops next to each other reduces the incidence and spread of pests and diseases.

Permaculture

Permaculture seeks to create an ecosystem that is self-sustaining, and that can thus continue to be farmed permanently. Permaculture is not a new kind of farming. It is a system that teaches how to do very careful thinking about all the relationships between plants, animals, and humans. It requires in-depth design, which often comes about only after many years of farming experience.

Caution

Intensive design planning does not fit into every culture. Also, because each year is different, and the climate is always changing, agriculture does not function well in rigid systems.

How to

Layout: The fields are laid out according to the amount of labor required. Livestock that are handled often are kept closest to the house, next vegetables and tree crops are planted, next staple crops, next pasture, and lastly trees for timber production. Wells are dug near the location where the water will be needed.

Systems: Systems are planned for composting, mulching, and utilization of manure. Also plants, crops, and pastures are planned to be able to feed livestock throughout the year. Crop rotations are planned to replenish the soil, and also to provide the right variety and enough quantity of food for the family. Crops are also chosen for their suitability for the time of year (wet season and dry season crops), and seed and plant material is saved for the planting of future crops.

Benefits

- **Sustainability:** If planned and implemented appropriately, permaculture can be sustained for very long periods of time.

Fish Pond with Farming

In areas with pronounced wet and dry seasons, fish ponds can be used during the wet season, and when they are empty in the dry season, vegetable gardens or crops can be planted in them. Fish ponds can also be used in conjunction with swamp rice farming, where nutrient-rich water from the fish ponds is drained into the rice paddies to fertilize the rice.

Caution

Ponds are breeding grounds for mosquitoes, which transmit malaria and other diseases. Consider doing a study of malaria incidence before and after pond construction. Consider raising a type of fish that eats mosquito larvae. Keep weeds out of the shallow water because mosquito larvae can grow there, protected by the weeds from being eaten by fish.

How

Fish pond construction: (see Agrodok 15, “Small Scale Fresh-water Fish Farming,” Resources page 41). Build fish ponds in low locations. Clay soil works best for making the walls and bottom of the pond. The pond should be naturally filled by a stream, ditch, or natural runoff after rains. It should also be in a location where it can be drained.

Fish pond gardening: In the wet season, crops can be planted around the fish pond. In some situations, when the dry season comes, the pond is harvested and the water is drained or dried up. Then vegetables or row crops can be planted in the bottom of the pond. The soil will be rich in nutrients, and will have moisture in the soil longer into the dry season.

Fish pond and rice: Fish ponds can be built just above (or up-stream of) rice paddies. This takes planning; you will need a channel that by-passes the fish pond to feed the rice paddies, and the ability to block this channel to fill the fish ponds. Expensive dykes are not necessary. You can divert water by filling up the channel with sand bags. When the fish ponds are harvested, the nutrient-rich water can be drained into the rice paddies. Alternatively, a portion of water from the ponds can be drained, and the ponds refilled regularly during the fish production cycle.

Benefits

- **Nutrients:** These systems take advantage of the nutrient-rich water, which is a by-product of fish farming.
- **Prevent Pollution:** Nutrient-rich water that is dumped directly into streams can have an adverse affect on the water supply and ecosystem by increasing algae and bacteria blooms. Using rice to “harvest” the nutrients out of the water is good for the ecosystem and the rice!
- **Water Conservation:** In the dry season you make use of the soil moisture that exists at the bottom of the recently drained fish pond.

Crop choice

If yield is consistently a problem, consider choosing a different crop that may be better suited to the area.

How to

Look at what farmers are growing in the area. Many farming communities have hundreds or thousands of years of experience, and have discovered which crops grow best. Conduct trials of imported varieties of common crops brought in from outside the region or country. Compare these varieties to each other and to the important local varieties.

Introducing a new crop: *CAUTION*, be sure to thoroughly test a new crop or variety before recommending it to farmers (see Sustainability, page 7).

Benefits

- **Quantity and Quality of Food:** Introducing crops that are more nutritious and that are better suited to the climate could increase nutrition and reduce hunger.

Plant Spacing and Planting in Lines

Too many plants per acre means that plants will compete for limited resources and light, and too few plants means that you have wasted space that could be productive. In some cultures, small seeds are scattered by hand rather than planted in lines, which leads to inconsistent germination and lower yields. While planting in lines with small-seeded plants is more labor intensive, it will reduce labor in weeding and harvesting, and will significantly increase yield.

Caution

In dry climates, more space between plants may be necessary because of limited water. This may initially give the impression that plants are too far apart. Be sure to test a new spacing before recommending it to farmers.

How to

Observation: Observe plants in the field at maturity. Do the plants touch each other or is there so much space between plants that weeds are growing? This will give you a clue as to whether you should try a closer or farther spacing.

Recommended Plant Spacing: Look up recommended row and plant spacing on the seed label (if one exists), in a tropical crops book, on the internet, or in Table 2 below. You might also ask a local expert. Compare what you learn to the spacing that is being used. Try a new spacing before recommending it to farmers.

Abara, South Sudan demonstration plot 1, month 2 (left), mulching and planting in lines with sorghum; plot 2, month 2 (right), mulching and scattering of seed. Plot 1 had a 30% higher yield at harvest than plot 2.

Planting small seeds by hand: After clearing the land (save plant material for mulching), mark a line with a long string attached to two sticks. Till with hand tools along the string marker. Make a groove or depression in the soil along the string with your hand. Using your hand or a cup with holes drilled in the bottom, scatter seeds directly into the groove, then cover the groove over with soil and pat it down. Move the string over to make the next row. To measure the distance between rows, use a stick that has been cut to the recommended row spacing.

Thinning: When planting small seeds in rows, thinning is critical. Go back over the field once the seeds have germinated and plants are 10cm tall. Pull out the weaker seedlings so that the distance between plants matches the recommended plant spacing. If this step is not taken, plants could be severely overcrowded, leading to a crop failure.

Planting large seeds: Measure and cut two sticks, one for the row spacing and one for the plant spacing. After clearing the land (save plant material for mulching), mark a line with a long string attached to two sticks. Lay down your plant spacing stick along the string, and till a hole at the end of the stick. Continue to move your plant spacing stick down the string, tilling holes as you go. Be sure that when you lay the stick down, you are measuring from the back of the last hole. The measuring could be made easier by preparing a string that has knots along it at the appropriate spacing. This would be especially helpful if a hand planter is available to you, so that you do not need to stoop down to drop the seeds. Once the holes are dug, plant seeds in each hole. Keep in mind that all the seeds might not germinate, so plant more than you need. Later, go back and thin seedlings to the appropriate number of plants per hole.

Planting with a seeder: Simple walk-behind or ox-driven seeders are available in some markets. This improved technology reduces the labor involved in planting, and increases accuracy of plant spacing. However, the technology may be unavailable or too expensive. In some places, a tractor-pulled seeder may be available for rent. Always compare the cost of renting such equipment with your expected yield, to see if you can recover the investment.

Benefits

- **Increased yield:** Finding the right plant spacing for your climate and land can increase yield, even if nothing else is changed. The situation may be more complicated if weather patterns are highly variable; the ideal spacing during a dry year would not be the ideal spacing if there is uniform rainfall. Where this variability is common and significant, the ideal may be somewhere in between the two extremes. In this case, one option would be to plant part of the field with one spacing and another part with different spacing, to ensure at least some harvest.
- **Reduced labor:** While planting may be more labor-intensive than broadcasting seed, planting in lines dramatically reduces the labor required for weeding and harvest.
- **Weed suppression:** When crop plants touch at maturity, the ground will be shaded, making it less hospitable for weeds.
- **Uniform harvest:** When plant spacing is uniform, plants grow and mature and are ready for harvest at the same time. If a staggered harvest is preferred, just stagger planting times.

Table 2. Recommended Plant Spacing for Various Crops. (Use these as a starting point.)

Plant	Row cm	Plant cm	Plants per hole
Sorghum 9-month	90	50	3
Sorghum 6-month	80	40	3
Sorghum 3-month	80	30	3
Millet	50	10	1
Cabbage	60	40	1
Tomato and pepper	90	30–60	1
Okra	60	20	1
Cucumber	90	30	1
Eggplant	90	45	1
Beans	60	30	1
Potato	90	25	1
Pumpkin or watermelon	200	100	1
Onion	40	10	1
Maize/Corn	75	60	2
Groundnut/Peanut	50	30	1
Sesame/Simsim	30–50	10	1

Pests

Chemical Pest Control

Chemical pesticides are expensive and dangerous to handle. They usually kill beneficial predator insects, as well as the pests. When handled, mixed, or applied improperly, they can cause serious illness and pollute the environment. (See Resources page 41, Agrodok 29, “Pesticides: Compounds, Use and Hazards”).

Non-Chemical Pest Control

See Agrodok 30, “Non-Chemical Crop Protection” for more information (Resources page 41). The remainder of this section on pests deals only with non-chemical pest control.

Observation

Pest control often requires critical thinking and observation. Observe the pest in question. How are the pests attacking the crop? Where do the pests live? How do the pests reproduce? Observing the pests will help you to determine what they are, how they hurt the plant, and maybe how to stop them! You may be able to observe predator insects that attack the pest, and learn about how to encourage their growth.

Biodiversity

This means that you have many different species of plants, insects, birds, and animals on your farmland. This diversity of living things helps to maintain the natural balance of nature. Different plants provide habitat for different types of insects, and can increase the number of predator insects (which feed on the pest insects).

Farming Techniques

Curved Rows

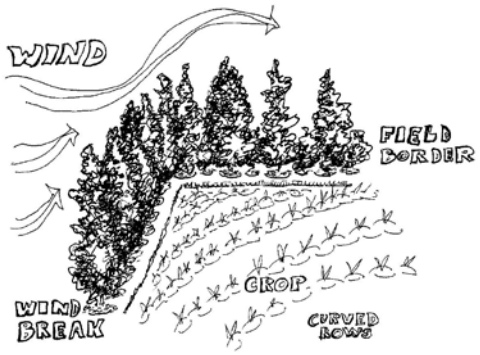
This confuses some pests and can slow down the speed at which they spread down the row.

How to: Rather than drawing out rows in perfect lines, lay out rows in a curved pattern.

Windbreaks

Many pests (and also spores of fungi) can be spread by the wind, which carries them to your field. Windbreaks can slow the spread of pests and some plant diseases.

How to: Plant windbreaks of trees or tall plants around your field, and in the field. You can grow leguminous trees as windbreaks and also get the benefit of improving the soil. (See “Alley Farming” page 16)



Leave some weeds

Sometimes weeds distract or confuse pests, harbor beneficial insects, or hide crop plants.

Example: A development worker along the Amazon River in Brazil had problems with a low-growing though not-very-vigorous vine coming up as a weed in his newly planted vegetable garden. He found that areas where he had cleared the weeds were severely damaged by iguanas, which went down the rows eating. The small vegetable seedlings were much less noticeable where they were surrounded by the weed.

Field Borders

Plant borders can be chosen that attract pests (to keep them at the periphery and away from the field), trap pests, or repel pests. (Agrodok 30, “Non-Chemical Crop Protection”). Like other non-chemical pest controls, this is only partially effective and must be combined with other techniques.

How to: Plant repellent plants around the field as a border, or in rows through the field. You can also alternate between repellent plants and trap plants as a cover crop.(Agrodok 30).

Repellent Borders

Here are a few examples of plants that repel certain pests:

- **Lemon Grass:** planted in the field, it repels some insects.
- **Desmodium:** planted in the field, repels some species of moth caterpillars.
- **Coriander:** planted in the field, it repels whitefly.

Trap Borders

Here is a plant that traps pests:

- **Napier Grass:** Planted at the border of the field, it attracts stem borer moths to lay eggs. When caterpillars begin to feed, the grass secretes a sticky substance that traps the stem borer larvae, so that they are easily found and eaten by predators. (Agrodok 30)

Predator Habitat

Field borders or plants spaced strategically in the field can serve as habitat for predator insects. For example, carrot or cilantro blossoms attract predatory wasps that lay their eggs in certain insects. (Note: ECHO's seed bank has a special carrot called "Uberlandia" that will bloom and set seed in the tropics. A side benefit is that farmers can then save their own carrot seed. One would not likely get carrot blossoms from the average commercial seed in the tropics, nor in temperate climates unless special techniques are used.) Observe the population of insects in your field. If there are few or no predators, you may not have enough biodiversity in your field. You can try mixed cropping, strip planting, or more diverse crop borders to encourage beneficial insects to come.

Crop Rotation

Pests are often crop-specific. By switching crops, you interrupt the life cycle of the pest. (See Crop Rotation, page 15).

Strip Planting

Crops are planted in strips, alternating between strips of crops, and a regenerative grass/legume mix or cover crop. (See Strip Planting, page 24). This increases biodiversity.

Inter-Planting Crops/Mixed Cropping

By planting two or more crops so that they are mixed up together, or in rows side by side, you increase the biodiversity of the field, which makes it more difficult for pests to spread and also increases habitat for beneficial predator insects.

Increase Soil Nutrients

Healthy plants can better withstand pest damage.

Local Remedies

Always ask local farmers what they use to kill pests. They may have recipes for making local plants into pesticides.

Pesticide Recipes

Homemade pesticides kill beneficial predator insects in addition to pests, and should therefore be used sparingly. Effective, safe-to-use pesticides can be made from a number of common plants. Soap is often a main ingredient of such pesticides. CAUTION: farmers should take great care when formulating homemade pesticides from substances that are toxic to humans, such as tobacco or castor oil (information from Agrodok 30). Many natural pesticide recipes can be found online. ECHO's publication "FAITH Gardening" has an excellent selection of recipes. See Appendix 1 (Home Pesticide Recipes) on page 47. The following are some of the many plants/products that can be used to make pesticides:

- **Soap**
- **Onions**
- **Garlic**
- **Hot Peppers**
- **Papaya leaf**
- **Neem:** The leaf and seed of the neem tree have a powerful compound that interferes with pest reproduction but does not harm humans. (See *ECHO Technical Note* on neem, and Agrodok 30 for more information). The leaf and seed can be made into a home-made pesticide, and the leaves can be buried to kill nematodes. As a development worker, you can obtain neem seeds from ECHO, free of charge (See Resources page 41). Check first, though, to see if neem is already grown in your area.
- **Cinnamon oil:** Can be used as an insecticide. It kills many insects, including mosquito larvae. Cinnamon oil comes from the bark of the Cinnamomum cassia tree, which grows in the tropics.
- **Marigold:** Leaves and flowers are used to repel pests.
- **Wood Ash:** Repels some pests.
- **Milk:** Can be used to make a fungicide.
- **Chalk dust:** Can be found naturally. When dusted on plants, it repels some small insects.

Erosion

Mulch

Mulch covers the soil, protects it from erosion and has many other benefits.

How to

Clear plant material from farmland, and lay it evenly across the ground or pile it around the individual crop plants. Do not mulch right up to the plant stems, as this may lead to rot and provide cover for certain insects to attack the stems. A deep mulch, six inches (15 cm) or so, is ideal for soil fertility, water retention, and weed control. However, locating and transporting that much mulch for field crops is unrealistic in most small-farm settings. Mulch of any depth will still reduce water evaporation and, to a lesser degree, erosion. In order to have sufficient material for mulching, a cover crop or hedgerow may need to be planted for the purpose of being used as mulch.

The layer of mulch closest to the soil will decay first. As it decays the mulch will get thinner, so continue to add more mulch on top.

Benefits

- **Erosion prevention:** Rain hits the mulch and then slowly trickles down to the soil, giving it time to soak in. When the soil is saturated, the mesh of decaying plant material slows down run-off and helps prevent erosion.
- See other Benefits–page 13

Contour Planting

By planting along the contour of a hill or slope, you can control run-off, capture more rainwater, and prevent serious erosion. Over time, natural terraces will form.

What is a contour? A contour line is essentially a level line that goes in and out according to the shape of a hill. The contour of the hill is always perpendicular to the flow of the run-off water. Every point along the contour line is at the same elevation. So if you plant along the contour, the plants and their roots act as a barrier to run-off. When the run-off water encounters the barrier, it would usually flow left or right along the row toward the lowest point, but because every point is the same height, the water slows down. When the water slows down, it drops the soil it is carrying, and more of the run-off water soaks into the soil.

Caution

When planting hedges or trees along contours, be aware that tree roots can be major competitors with crops for water and nutrients.

How to

Mark the Contour: It is important that the contour be actually level, and not just a guess at level.

Construct an A-frame Level: You can construct a simple tool, called an A-frame level. Collect three long straight strong sticks/poles (at least 1 meter long), a rock, a string, and a few nails. Nail the three poles in the shape of an “A”. The width of the bottom of the “A” should be the same as your planting distance, or a fraction/multiple of your planting distance (for example, for trees on a 3-meter spacing, make your frame 1.5 meters wide, and only mark every other time, or for plants spaced 10cm apart, make your frame 1 meter wide, and know that you are marking every tenth plant). When the frame is nailed together, tie the string to the top point of the “A”. The string should hang past the cross bar of the A. Tie a rock to the bottom of the string. (see diagram). If the A-frame is not stable, cut and nail an additional crossbar lower down.

Pastors at a workshop in Kajo Keji, South Sudan, construct an A-frame level.

Calibrate the A-frame: Place the A-frame on slightly uneven ground. Mark the places on the ground where the two feet of the frame sit. Then mark on the crossbar the ex- act place where the string touches it. Carefully lift the A-frame, turn it around, and place the first foot in the place where the second foot was before, and the second foot where the first foot was. Now mark where the string touches the crossbar. Measure between the two marks on the cross bar you just made, and make a larger mark half way between the two marks. This larger mark is your level indicator. When the two feet of the A-frame are at the exact same level, the string will hang down and touch this center mark on your cross bar.

Use the A-frame: Mark where you want your first plant to go on the contour line you intend to mark. (Sticks with a sharpened end work well for marking.) Place one foot of the A-frame next to your first marker. Move the second foot of the A-frame around until

the string rests exactly where your calibrated center mark is on the A-frame. Mark where the second foot is with another stick. Continue until you reach the end of your row. The row will look messy, in a zigzagging pattern. But as you walk the line you have marked, you will notice that you never take a step up or a step down, you have marked a perfectly level line.

Plant along the contour: Prepare your raised seed bed along the contour line, and plant along the row you have marked, according to the plant spacing requirements. Walls/barriers: You could also build a short rock wall along the contours leaving space between the contours for planting. Or you could dig ditches along the contours, and pile the dirt along the contour to make a barrier. These walls or barriers will interrupt the flow of water down the hillside, and slowly with time (if you repair and build up the barriers after the rains) erosion between the barriers will cause natural terracing.

Alley Farming: Combine contour marking with Alley Farming (page16). Plant hedges (closely planted shrubs or trees) along contour lines. Leave space between hedgerows to plant your crop rows. The roots of the hedge provide greater stability to your slope, and the leaves can be used as mulch (or as a crop or livestock forage when appropriate plants are selected). With time (depending on rainfall) the hillside will erode between the hedge rows, to form natural terraces on the hillside.

Benefits

- **Erosion Prevention:** Without erosion, the topsoil will deepen, more nutrients will remain on the hillside, and yield will improve.
- **Rainwater Capture:** With hedges planted along contours, approximately 90% of rainwater is retained on the hillside. In contrast, without barriers, approximately 90% of rainwater that falls on a slope, runs off, so only 10% of rainwater soaks into the soil profile. (info from Alley Farming of the Tropical Agriculturalist Series, see Resources page 41)

Strip Planting

A modification of “Contour Planting” above. (Agrodok 11, “Erosion”)

How to

Plant in strips across a hillside following the contour as best you can. Strips can vary in width, starting around 5 meters. Alternate between strips of crops, and strips of grass/legume mix. The grass legume mix fixes nitrogen and reduces erosion. This method can be switched up to become “Crop Rotation” or “Fallow” (see pages 15–16), if every couple years, you switch the strips: cultivate the grass strip, and leave the previously cultivated strip to be “cover-crop.”

Benefits

- **Prevent Erosion:** The strips of grass hold the soil in place, slow down the flow of water down the hillside and provide feed for livestock.
- **Soil Fertility:** The legumes and the method of crop rotation improve the fertility of the soil, and reduce soil pests.

Reduce Tillage

Do this to reduce labor and loss of topsoil carried away by erosion.

Caution

Weeds may become a problem with reduced tillage. Slashing down the weeds before they set seed and using them as a mulch or livestock feed may work effectively to suppress weed growth. Alternatively, use a cover crop.

How to

Reduce tilling as much as possible. Leave the stubble in place from the last crop, and till just where you intend to plant. (e.g., use a hoe to till approximately 30cm around each place you plant a seed).

Benefits

- **Reduce erosion:** Natural (untilled) soil structure with dead roots and decaying plants stays in place better than tilled soil.

Drought

Early Planting

By preparing seedbeds and planting before the first rain, you take advantage of the early rains and get more growth. (Gibbon, 18-19)

Caution

Leaving the seed in the soil for too long may lead to losses from scavenging birds, animals, and insects. Also, if wind erosion is a problem during the dry season, do not use this technique, because tilled soil will blow away more quickly.

How to

Prepare the soil: At the beginning of the dry season, prepare your field or seedbeds. There is still some residual moisture in the soil at the beginning of the dry season, which makes it easier to till/hoe the soil and to form seedbeds.

Plant the seed: Just before the first rain, plant your seed. This timing is important. Because the soil is very dry, the seed will not germinate.

Benefits

- **Maximize Rainwater Use:** Most farmers wait until the first rain to till the soil, because after the dry season the soil is hard. In this case, by the time the seed is planted, much of the water from the first rain has moved beyond the seed zone or evaporated.

Planting in Holes or Furrows

Holes and furrows collect rainwater and move the root zone deeper where there may be better water holding capacity. By adding decaying plant matter and compost to the holes, you concentrate the nutrients at the plant root zone and encourage worm and termite activity, which increases water penetration into the soil (info from *Amaranth to Zai Holes* see Resources, ECHO page 41).

Caution

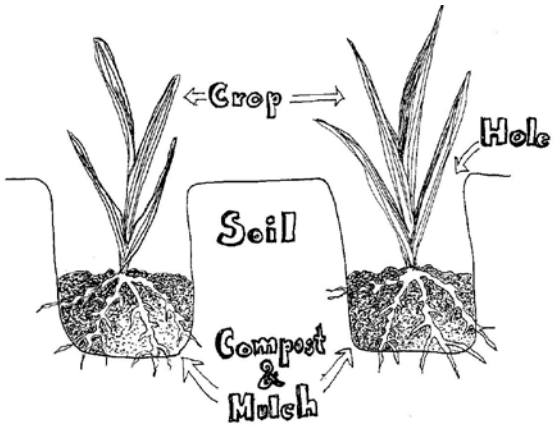
If the first rain is not significant, the seed may not get enough moisture to germinate–especially if the soil is covered with dry manure and/or mulch. Check the holes after the first rain, if the seed zone is not wet, consider irrigating at least once, if that is an option.

How to

Furrows: Dig furrows that follow the contour of the hill (see Contour Planting page 17), so that water does not run off. Dig channels that direct run off to your planting area. Dig/form basins which collect rainwater, and plant trees or groups of plants in the bottom of the basins/furrows.

Zai Holes: (info from *Amaranth to Zai Holes* Chapter 7)

Dig a hole: Dig a hole for each plant at the beginning of the dry season. You can vary the size of the hole, but the recommendation is 20 cm in diameter and 10 cm deep. If the topsoil is very thin, you may want to dig the hole a little deeper, and then put the topsoil back into the hole.



Mulch: Fill the freshly dug hole with mulch (crop residue works), and some manure if available. The mulch adds nutrients and encourages termite activity, which will increase rainwater penetration.

Plant: Plant seeds in the hole after the first rain, or irrigate.

Benefits

- **Maximize Rainwater use:** Holes and furrows collect water, delivering it to the root zone, and termite activity increases penetration of the water.
- **Wind break:** If wind damage is a problem, the hole helps protect the seedling from the wind.

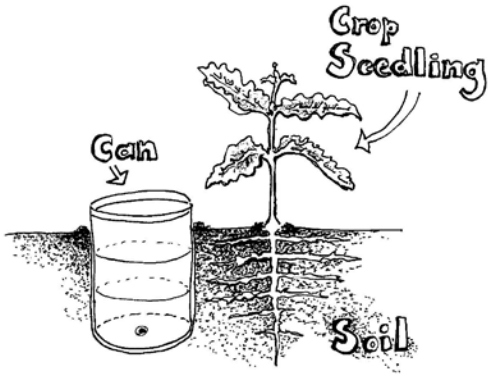
Direct Root Zone Watering

If water availability is limited, drip irrigation makes better use of limited water resources by concentrating that water in the root zone, and by not allowing any run off. It also minimizes labor. But often drip irrigation is not an option because of location, fear of theft, cost, lack of equipment or plants, such as trees, that are too far apart to use drip irrigation.

An alternative that costs nothing other than labor can be used to establish trees and plants during the dry season or for supplemental irrigation during the growing season.

How to

The goal is to ensure that water that is carried and poured by hand ends up in the root zone and away from sun and wind, rather than spreading on top of the soil and possibly never penetrating to where it is needed.



Make one or a few small holes/depressions around each plant. The hole(s) can be left open or filled with rocks or gravel. Alternatively, you can place a bottle, can or pot with holes in the bottom into the hole and replace the soil around the container. (An advantage to using a container instead of rocks is that soil or debris is less likely to fill the space; the container can be easily removed and emptied if it does fill up.) Similarly, for a row of closely-spaced vegetables, make a small trench alongside the row and pour the water into the trench. If the water in your container is not draining quickly enough and begins to evaporate, add more holes in the bottom, or find something to cover the container to reduce evaporation.

If fertilizer or compost is available, it can be concentrated in the bottom of the irrigation hole or trench, where nutrients will more available to the roots.

Benefits

- **Water Conservation:** Water is delivered directly to the root zone of the plant, so that it is efficiently used.
- **Reduced labor:** After the initial labor of installation, it will take significantly less time to water your plants.
- **Weed prevention:** Because the surface remains dry, fewer weed seeds will germinate.

Erosion Control

The results of erosion are often quite visible. Less obvious to the naked eye is the loss of valuable rainwater that caused the erosion. See Erosion (page 23) for ideas for controlling erosion, including contour planting.

Mulch

Mulch covers the soil and protects the soil surface from the strong rays of the sun. It also prevents water run-off (and soil erosion), so that more rainwater penetrates the soil.

How to

Clear plant material from farmland, and lay it evenly across the ground or pile it around the individual crop plants. Do not mulch right up to the plant stems, as this may lead to rot and provide cover for certain insects to attack the stems. A deep mulch, six inches (15 cm) or so, is ideal for soil fertility, water retention, and weed control. However, locating and transporting that much mulch for field crops is unrealistic in most small-farm settings. Mulch of any depth will still reduce water evaporation and, to a lesser degree, erosion. In order to have sufficient material for mulching, a cover crop or hedgerow may need to be planted for the purpose of being used as mulch.

The layer of mulch closest to the soil will decay first. As it decays, the mulch will get thinner, so continue to add more mulch on top.

Benefits

- **Soil moisture retention:** protects the soil surface from drying.
- **Rainwater penetration:** prevents water run-off.
- **Reduction of erosion**.
- See other benefits of mulch on page 13.

Shade

Shading the soil surface and plants from the sun reduces evaporation of soil moisture and reduces sunburn and withering of the plant. Temperate vegetables in particular may benefit from some shading when solar intensity is high.

Caution

Shade can also reduce yield, so know your plants! In subtropical regions, shade may be beneficial when the sun is nearly overhead but may reduce light too much when the sun has retreated toward the opposite hemisphere. Also, when using trees for shade, competition of tree roots for water may make the effects of drought worse for the crops.

How to

There are many ways to create a shaded environment for plants. Look for what materials are most readily available in your area.

Branches: Branches of trees (leaf trees or palm trees), or large leaves can be used to make shade. Stick the branch or leaf in the soil next to the plant so that the leaves provide shade. Individual shade huts can be formed by cutting up palm branches, then bending the pieces into a circle and placing the ring around the plant.

Shade structure: A thatched shade structure can be built over the plants (this is more labor- and material-intensive).

Mulch: See "Mulch" above for keeping soil temperature lower.

Alley Farming: See Alley Farming page 16.

Tree Crops: Combining tree crops with row crops provides some shade to the row crop. The trees can be pruned back some during the rainy season so that they don't shade the crop too much. Shade trees can be planted alongside crops requiring shade like cacao and coffee.

Forest Farming: When farming in a naturally forested area, some scattered trees can be left in the field and pruned back as appropriate to provide partial shade and mulch through leaf fall.

Benefits

- **Water Conservation:** Keeps rainwater from evaporating.
- **Yield Maintenance:** Partial shade can protect plants from sunburn, wilt, and die-back, which could reduce yield.



(Left) Palm fronds are tied in a circle to provide shade for seedlings, in this demonstration at an agricultural fair in Ganta, Liberia. (Middle) Teak leaves are used to shade newly transplanted tomatoes in Yei, South Sudan. (Right) Grasses are used to give shade and protection from heavy rains to seedlings in Yei, South Sudan.

Rooftop Rain Catchments

In dry climates, every roof has the potential to collect rain–but the supplies can be expensive.

Caution

Water stored where mosquitos have access can lead to a significant increase in mosquito-borne diseases. Small minnows that eat mosquito larvae might be introduced into ponds and barrels, but may not be suitable for water intended for human consumption.

How to

Direct Water to the Storage Container: Purchase or build an eaves trough (also called a gutter) and attach it to the edge of the roof. A simple gutter can be made from a sheet of thin rust-proof metal (aluminum is ideal) that can be formed into a U shape. Alternatively, look for materials that already have a curved shape, such as bamboo poles or plastic pipe that can be cut in half length-wise, or hollowed out wooden poles. Slope the gutters downward toward a common location.

Closed Water Storage: Obtain a tank or barrel to catch and store the rainwater. (Tanks and barrels can be expensive or difficult to locate.) Place the tank or barrel at the place where water runs out of the gutter. The tank or barrel should be closed with a lid when it is not raining, to prevent evaporation.

Open Water Storage: Build a small pond. If soil is heavy clay, you might be able to just dig the pond into the soil. If the soil is water permeable, the pond can be lined with plastic or cement.

Benefits

- **Water conservation:** Collects precious rainwater and makes use of existing structures.

Crop Selection

Choosing the right kind of plants is critical. Some plants are more drought tolerant than others.

How to

Trees: Established trees or large bushes have deep roots and are more drought-tolerant than annual field crops or vegetables. Some drought-tolerant tree crops include date palm, moringa, cashew, and pomegranate (see *Amaranth to Zai Holes* Chapter 7 for more).

Field Crops: Sorghum is more drought-tolerant than maize, and millet is more drought-tolerant than sorghum. Cassava, lablab and pigeon pea have considerable drought tolerance. For more crops, read chapter 7 of *Amaranth to Zai Holes* (available for free online). See Resources, ECHO page 41.

Benefits

- **Increased Success:** Crop failure is less likely in the event that rainfall is less than expected.

Household Water Conservation

Save the water you use in your household.

Caution

Water that may contain feces (sewage or water from washing diapers etc.) contains disease organisms and should not be used.

How to

Collect water you have used for dish washing, laundry, or bathing, and use it for watering the garden.

Benefits

- **Water Conservation:** Make use of existing water.

New Water Sources

If water conservation isn't enough, wells and reservoirs can be constructed, but usually at a great cost. In areas where people dig for water in a river bed, a "sand dam" can be built across the river. This is a cement dam, which goes down to the bedrock. During seasonal rains, the area upstream from the dam fills in with water-saturated sand, which significantly increases water availability in the riverbed during dry periods. This can be very effective but is also very expensive.

Fish Pond with Farming

See page 18.

Flood

Drainage Ditches

Channel the flood water away from your crops, by digging ditches. Keep in mind your ditch must lead to lower ground, and the bottom of the ditch must at all times be lower than the lowest point of the flooded ground. If flooding comes seasonally from a river, you may consider a levy building project.

Planting in Mounds or Raised Beds

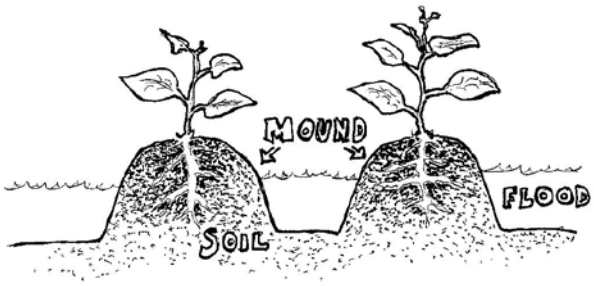
This technique keeps the roots, or most of the root zone, above the standing water or water-logged soil.

Flooding, Usulutan Province, El Salvador, 2007.

How to

Mounds: Till or hoe the dirt, and pile it into mounds roughly 30cm high and wide, or whatever is most suitable in your situation. Plant one plant or a cluster of plants in each mound (depending on your desired planting distance).

Raised Beds: Till or hoe the ground, and form it into a long raised bed of soil. You can vary the height and width depending on the depth of flooding you expect, and the plant distance required.



Benefits

- **Protection from Rot:** Raising the root zone can protect your plants from some flooding, which can cause rot.
- **Protection from Tuber Damage:** Planting in mounds also makes it easier to harvest tuber crops without damaging the tuber.

Crop Choice

Choose a crop that does well in your area under flooded conditions. Tuber crops are more susceptible to rot in flooded conditions, so should be used with caution. Ask local people what crops can survive flooded conditions. Rice and taro tolerate flooded conditions well. Some fruit crops, such as guava and coconut, also tolerate flooding well.

Urban Agriculture

Where there is very little or even no arable land for agriculture, people may still be able to grow some of their own food. Plants can be grown in containers or small raised beds in many situations: in courtyards, on rocks, paved areas, balconies, rooftops or where soil has been contaminated. See *Agrodok 24, Urban Agriculture* (available for free download) and ECHO's Technical Note on rooftop gardening. You can view an extensive narrated self-showing PowerPoint on ECHO's website that explains several methods ECHO recommends for these challenging situations. (see Resources, page 41)

Safety

Be aware of potential dangers involved in growing food in urban areas or along busy highways. Heavy metals (from traffic or industrial emissions) and harmful chemicals are more likely to be found in soils in these settings. Though dangerous bacteria and other disease pathogens can be found in the soil and manure used on farms, the dangers may be more likely to cause human diseases if poor sanitation results in soil or water that is contaminated with human pathogens. This is more likely to occur in urban settings. Common sense and observation may alert you to some of these hazards. Less apparent will be contamination caused by past emissions from smokestacks, or by lead (from emissions from passing traffic, or paint from dismantled buildings). Unless you are working with a well-funded urban gardening project, testing for these potential contaminants will probably be prohibitive. One way to avoid this danger is to grow food in containers known to be clean, or on cement pads or on soil that has been covered with a sheet of plastic. Uptake of heavy metals from the soil by plant roots is considerably lessened if you can build up a high level of organic matter in the soil. Read Agrodok 24 for more safety tips.

Compost

See composting on page 14. Compost is critical in urban agriculture, because you can grow your plants in compost that you have made and that you know to be free from dangerous pollutants and disease pathogens (note: if compost is not made correctly it may still contain disease pathogens). After you have used the compost/soil once (harvested the crop), you may want to discard it. The used soil will be exhausted of nutrients, and possibly be infected with plant pathogens or pests.

Containers

Growing crops in containers is a great way to produce food in an urban area.

How to

Many different things can be used as containers: plastic or metal containers of many sizes, tires, plastic bags, sacks, canvas, wood, or anything else you can find. Make sure that there is a hole in the side of the container for drainage, and fill the container with compost/soil.

Carpet

One of ECHO's favorite and quite successful methods is to make a planting bed consisting of a thin layer of compost or soil placed on top of an old carpet or thick pieces of cloth. If soil is not available but complete fertilizers (i.e., ones that contain all nutrients needed by plants) are, you can safely omit the soil. In that case you would say that you are growing the vegetables hydroponically.

How to

A carpet with longer fibers (i.e., shag carpet) works best. Germinate your seeds, and start your plants in compost or soil, then transplant seedlings onto the 1 to 2 centimeter deep seedbed of compost or soil layered on top of the carpet. The roots grow into the carpet and any soil or compost you may have placed on top of the carpet. The wicking action of cloth in the carpet will distribute water throughout the carpet and any soil/soil mix that is on the carpet. Because the total volume that can hold water is much less than in a normal container, you will need to water often. You will also need to include a complete fertilizer on the carpet or in the water, unless a very fertile soil layer is present. (You can use compost tea, or some other homemade liquid fertilizer, but it is difficult with either of these to ensure that every nutrient needed by plants is available in necessary amounts.)

You will need to cover the carpet with something to help keep the moisture in and to give support to the plant stem: this could be a mulch of plant material, or even something like gravel, pine cones, corn cobs, or coconut husks. Plants may not grow as well using this system as they would in a container of ideal shape with an ideal soil or compost, but any difference should be made up by the much lighter weight and less volume of compost you need to make. (Technique seen at ECHO's demonstration garden, see Resources page 41).

Storage and Preservation of Food

Common spoilage of stored food is caused by mold/decay, physical loss, rodents, or insects. Aim for dry, well-ventilated, well-contained storage, with rodent and insect prevention.

Preservation Techniques

Food can be preserved in many ways: e.g., drying, smoking, salting, fermenting or canning. Common preparation steps include milling, chopping, skinning, and removal of seeds from fruit. See postharvest Agrodok titles, Resources, page 41.

Common Storage Locations

Sack

Grains, seeds, and other dried food for storage are commonly kept in grain or feed sacks (large woven jute or plastic sacks). The weave in the sack allows some ventilation and also some water resistance.

Benefit

- Using sacks reduces physical loss by containing the food in a bag. It deters rodents and insects by containing the food (no spillage to attract pests).

Rice Kitchen, in Zorzor, Liberia. Rice is kept in sacks in the loft. Cooking fires underneath keep the rice dry and smoked, preventing mold and pests.

Attic

Food can be stored in stacks in an attic storage place. The ideal roof design would allow for some ventilation through the walls and floor of the attic, and would provide protection from the rain.

Benefit

- Good ventilation and protection from moisture reduces mold.

Storehouse or shed

A storehouse is a separate building where food is kept. Sometimes food is kept in heaps (which attracts rodents and insects, and can cause spoilage from mold). The best way to prevent physical loss (due to trampling and wind), and to deter pests and prevent mold, is to store food in sacks that are stacked on pallets (or a rack that allows some ventilation under the sacks). The pallets should be kept away from the walls and away from areas where rainwater comes into the building. The storehouse should always have a good roof and good cross ventilation.

Traditional grain storage in Terkeka South Sudan. Mud lined baskets suspended on stilts, moderate protection, but still suseptable to mold and pests.

Benefit

- Keeping food in a separate house allows farmers to have better control over the environment where they are keeping the food.

Tank

Tanks are prohibitively expensive in most places. However, they prevent rodent damage, and keep the stored food watertight.

Caution

- Ventilation does not exist in a tank, so if there is any residual moisture in the food that you are attempting to store, it can mold. Some molds found in stored grains and pulses are known to cause cancer.

Benefit

- Prevents rodent damage and rain damage.

Pest Prevention Techniques

Rodent Prevention

Cleanliness and Containment

Store food items in containers (e.g., sacks, barrels, tanks, etc.) that are difficult for rodents to penetrate. Keep the storage area clean, with open areas around where the food is kept. Spilled food attracts rodents. Rodents like to stay hidden, so keeping food in the middle of a store room with space around it will deter them slightly.

Elevated storage with metal sleeves

Rodents cannot climb smooth metal surfaces. You can build a store shed on stilts, and surround each leg of the shed with a narrow sheet of metal (this metal sleeve must be wide enough that the rodent cannot jump past it). You can also fashion the metal sleeve in the shape of a cone with the larger end pointed down. (see Rice Kitchen diagram next page).

Rodent Extermination

Predators

Keep cats or other animals that will hunt rodents.

Mechanical Traps, Glue Traps, Poison

These and other local rodent extermination techniques are often available in a local market.

Caution: Extreme caution should be used when using poison in a place where food is stored. Be sure that neither poison nor dead animals come into contact with food. Do not use poisoned grain, as rodents may carry it off and could mix it with the food supply.

Insect Prevention

Ask local people what plants or methods they use to keep insects away from their food.

Smoke

Smoke from a wood-burning fire is a deterrent for many insects. Use smoke as a deterrent by building a fire under an elevated storage shed, or by wafting smoke into a storehouse or attic.

Neem leaf

The leaf of the neem tree repels insects, but is not harmful to humans. You incorporate dry neem leaves into your sacks of dry food to deter insects. (see Neem page 22)

Example Storage System

Rice Kitchen

How to

An open-sided shelter is constructed on four poles. The roof will be the shelter for the food storage attic and for the kitchen area which will be set up under it. A water-tight tin roof or a thick thatch roof is constructed. A support for the ceiling is built under the

roof out of poles and a woven grass/reed mat. The sides of the roof face the prevailing wind direction. The roof has a good overhang. The open ends of the roof provide ventilation, and can be protected from rain by erecting slats of tin roofing or by using a grass/reed mat. Finally, metal sleeves can be put on the four poles of the structure to deter rodents. The act of cooking on a fire every day keeps the rice storage attic dried out, and the smoke seeps into the attic and deters insects.

Benefits

- Prevention of mold, rodent, and insect problems. Makes use of fire and smoke which must be made daily for a different purpose.

Livestock Problems

See Animal Science for Beginners, page 5. Use Assessing Livestock Production, page 11, to identify specific problems. Based on the problems you see, use these four easy steps to improve livestock production. For more information download the Agrodok series (see Resources, page 41).

Feed and Water

Water

Water is critical. Constant access to clean water is best for the animal though not practical in some systems. Give water to the animal at least twice a day. The water in a public watering hole is usually contaminated with parasites and disease organisms. The worst watering hole is one that the animals walk down into, because the water is contaminated with manure. Obtaining clean water from a well or bore hole is best, but sometimes is not available or is expensive.

How to improve: Bring clean water to your animals at least two times a day. If they are confined, supply them with a constant trough of water. Note that in some communities farmers may believe that certain animals get all the water they need from green fodder. Though the animals may not die without additional water, they will do much better if given water.

Feed

Be sure that your animals have access to adequate feed.

Signs of malnutrition: rough dull hair, ribs and bones poking out, lethargic attitude, large head with small rib cage (sign of protein deficiency in young), small size in relation to age, and a general failure to thrive.

Signs of over-feeding: Animal becomes very fat. Overfeeding of high protein foods can also cause diarrhea. Consistent overfeeding can lead to joint problems.

Types of feed: Beans, dark green plants, seed cake, fishmeal, bone meal and blood meal are high in protein. Grains, sugars, and oils/fats are high in energy. However, different species require different kinds of food based on their digestive system. See Agrodok 1 Pig keeping in the tropics and Agrodok 4 Small-scale poultry production in the tropics on calculating feed rations and feed types. Also see *ECHO Development Note* #97 Resources page 41.

How to improve your feed: Ruminants, **hindgut fermenters**, and **pseudo-ruminants** need plenty of forage. Cattle, sheep, and horses will eat mostly grasses, but goats and rabbits like a variety of greens to choose from. When growing or lactating, these animals may need additional higher-quality feeds with more protein and energy. Working animals will need additional energy feeds. Ruminants need at least 2/3 of their feed in roughage (plants), and the dry weight of roughage must be between 2 to 4% of the animal's body weight (depending on species, and maintenance vs. growth). See Agrodok 14 "Dairy Cattle" and Agrodok 7 "Goat Keeping" for more information.

Monogastric animals need a diet with an appropriate level of protein. Pigs need 13% protein just to survive, and 20% to produce milk or grow. Poultry need 16.5% protein to produce eggs. Hungry chickens will begin attacking each other, and many will die. Most grains are approximately 10% protein, and beans are approximately 20 to 30% protein. In general a mixture of 1 part beans to 2 parts grain will be approximately 13% protein. Use the Pearson's square method to calculate your exact feed ration, using Agrodok 4 pages 41-44.

Pigs will also do better if they have some variety in their diet, such as greens and vegetables from the garden. Moringa leaves or leaf powder are an excellent source of protein, vitamins and minerals, which can be added to feed. (see Moringa, page 36). See Agrodok 4 for calculating feed rations for poultry, and Agrodok 1 for suggestions on feeding pigs.

Where to get feed Forage/Fodder: Often subsistence farmers with only a few ruminants can get most of the forage by allowing the animals to roam free along roadsides or, during the dry season, in dormant fields. Growing feed for animals may seem strange to these farmers. ECHO once held a forage variety trial in Haiti, but learned that local farmers found it puzzling and a waste of time.

However, farmers with many animals find that the number of animals they can keep alive for a year or more depends on how many they can feed during the last months of the dry season. To increase this number, you can plan ahead to be sure you

are growing the forage or fodder you need. Rather than harvesting and storing forages as hay for winter feeding as farmers in temperate climates do during the summer, you could consider having a forage bank. A forage bank uses perennial forages or trees that can be harvested and hand-carried to animals when other forages are not available. This can be grown on land not otherwise well adapted for cropping, e.g., along borders of the fields or on steep hillsides. You can improve the quality of this forage by including legumes in the forage bank. Alternatively, you can inter-plant food/feed crops such as pigeon pea or lablab beans that will produce seed for consumption and that will continue with green leaves during or well into the dry season.

Protein and energy sources can be expensive to find. Look for what is available and cheap on the market. What is the cheapest grain? What processing facilities are producing edible waste (e.g., oil seed production, slaughter house). What seasonal crop surpluses exist? You can also grow your own feed crops.

Improving Your Livestock Keeping System

Uncontrolled Livestock Keeping Systems: Animals will find their own feed, but this system leads to high death rates. It would be better to confine the animals during the night hours, and to supply them with clean water, some supplemental feed, and a mineral block.

Semi-Intensive Livestock Keeping Systems: Semi-intensive systems give keepers some flexibility in feeding. The animals are able to look for some or most of their own food, so the animals will seek out the types of plants they need in their diet (if there is enough choice). Keepers must be sure the animals are getting enough feed.

- When animals are tethered, move them often, or cut extra feed and bring it to them.
- Fenced animals may need extra feed brought to them. If grasses have been grazed down to 1/3 their original height, animals should be moved to a new location, or given extra feed. If grazed past that point, the grassland or pasture may not be able to regenerate.
- Consider rotational grazing with pasture animals; in this case, animals are confined to a section of the pasture for a short time (not exceeding three months) and are then rotated, allowing time for parasite eggs in the pasture to die and for the grasses to redevelop.
- When ruminants are pregnant, nursing, or young and growing, they should be given access to an increased amount of feed, especially of dark green leafy plants. Also consider giving a supplemental feed that is high in protein and energy.
- Mineral blocks and salt licks can be made, which will improve the health and digestion of ruminants. See *Agrodoks 14* and *7* for suggestions on making feeds and mineral blocks.

Intensive Livestock Keeping Systems: Keepers are responsible for bringing all of the nutrition that the animal needs.

- Keepers must be careful to provide the right mixture of feed, including the right quantity, and the correct mixture of protein, energy, roughage, and minerals. (See How to Improve Feed, above).
- Keepers must be vigilant in watching the health and condition of the animals, and change the feed ration when they notice problems.
- Keepers must watch the feed they have stored, both dry roughage and supplemental feed, for signs of mold or rot. DO NOT give moldy feed to livestock. Mold can poison the livestock and kill them. Ruminants have some resistance to moldy feed, but it is not advisable to give them moldy feed.

Selective Breeding

Read the sections “What are the facts about Breeding” and “What do I need to know about genetics” under Animal Science for Beginners, page 5. Selective breeding is critical to the long-term success of a livestock operation. If animals are allowed to breed at random, siblings may breed each other, and parents breed with their offspring, causing a concentration of weak traits and even deformity and disease. If the poorest quality animals in the herd are not removed, they will breed with the better animals, reducing the potential quality of the next generation. Selective breeding cannot happen in an uncontrolled livestock keeping system, because it takes careful observation and the ability to confine animals temporarily.

How to breed

Follow these steps when breeding animals.

Select a breeding pair

Evaluate the quality of the female you want to breed. What are her good traits? What are her poor traits? Choose a male who has good traits that she lacks. If this will be her first pregnancy, you may want to choose a male that had a low birth weight, or whose offspring have low birth weights, to ensure an easy first birthing. (It can endanger the health of the female if she is bred to a male of a much larger breed of the species.) It may be necessary to purchase, borrow or trade for a new male of very good quality every few years. This way you are bringing new genetics into your herd, and you will improve the herd more rapidly.

Observe

Watch female animals who have reached puberty. If they are not at least 3⁄4 of their full adult weight, confine them when they show signs of heat, so that they will not be bred until they are bigger. If they are of an appropriate size to breed, watch for signs

of heat (see Table 1 on page 6 for signs). For most species the female will become agitated the day before. On the day she is in heat she will be very friendly with the male, and will stand to allow other females or males to mount her.

Confine

When the female shows signs of heat, remove her from the herd, and bring the chosen male to her.

Breed

Allow the male to breed the female. This can be done in a pen, or with two handlers, one holding the female, the other leading the male to her on a rope line.

Confine

Do not return the female to the herd if there are males in the herd. If she is in heat a second day, breed her to the selected male again.

Record and release

Record the breeding dates and the male used. Return her to the herd when she is no longer in heat.

Confirm pregnancy

Check Table 1 on page 6 to determine the length of the estrous cycle. For most livestock it is 21 days. So 21 days after breeding, observe the female to see if she is coming back into heat. If she is, then she is not pregnant and needs to be bred to the selected male again.

Record

If the female does not come into heat, then she is pregnant. Record the expected birthing date in her file. Check Table 1 on page 6 to see how long the gestation period is. You get the birthing date by adding the gestation period to the breeding date.

How to cull

The next step to selective breeding is culling, which means removing undesirable animals from your herd.

Records

By keeping records of the important statistics and information about your animals, you can see which ones are the best and which are the worst over time. The important events include: birth date, weaning, time required for growth to maturity, and date(s) of slaughter or breeding and birthing. The date, the weight of the animal, and the overall health or quality of the animal are useful data to have for each event. It is also useful to keep track of productivity in dairy livestock or in egg laying poultry (i.e., record liters of milk or number of eggs per day).

Slaughter

If you are raising meat animals, choose the poorest quality animals to slaughter first. This can be controversial in cultures where the best animal is traditionally slaughtered for a feast, wedding gift, or sacrifice. However, if culling and selective breeding are done, over time all the animals will be of a quality good enough for feasts and gifts.

Sell or give away

If the animal is not for slaughter, find a way to remove it from your herd.

How to improve care

The next step to selective breeding is improving the care of pregnant and birthing females, and newborns. Remember that these offspring are going to be better quality than their parents, so you want to invest in them to give them the best start possible.

Birthing

When the time is near for the female to give birth, bring her into a pen where she can be watched. Her behavior will change the day before she gives birth. Look at the Agrodok handbook for the appropriate species to see what these signs are. Give her privacy during the birthing process, but be nearby to assist if necessary. Look at the Agrodoks or a veterinary book to see what normal birth should be like.

- If you do have to assist in the birthing process by pulling on the baby, do so gently, and lubricate with a veterinary lubricant or clean vegetable oil.

- Clean around the baby's nose so it can breathe, but then leave the baby for the mother to clean off.
- If you need to assist, record this information in the file of the female, because this is a bad trait that you do not want in your herd (unless it is her first pregnancy, in which case she may not be fully grown).

Observe

See that the mother takes care of the baby, and that the baby stands up to nurse within a few hours of birth. Mothers that do not care for their young should be removed from the herd.

Assist the baby

If the baby does not stand to nurse, you can help it, by holding it to nurse. If it has been a long time, and the baby has lost energy even to suck, you can milk the mother, and pour it down the throat of the baby using a tube and bag. Be sure the tube does not go down the airway (watch for coughing or check for breath coming out of the tube), and that the tube and bag have been cleaned with boiled water. If the baby has to be assisted in this way, this is a bad trait, and should be recorded in the file. This would be an animal to cull when it reaches slaughter weight (unless it is exceptional in every other way).

Feeding

See the section on feeding above. Proper feeding of lactating females and growing young is critical for their development, so that they reach their maximum potential.

Protection

If livestock are being lost to thieves, predators, or injury, the livestock keeper needs to change his/her method of protecting the animals.

Goat and sheep night time shelter an chicken shelter, in Ibba, South Sudan.

Improving Your Livestock Keeping System

Uncontrolled Keeping System

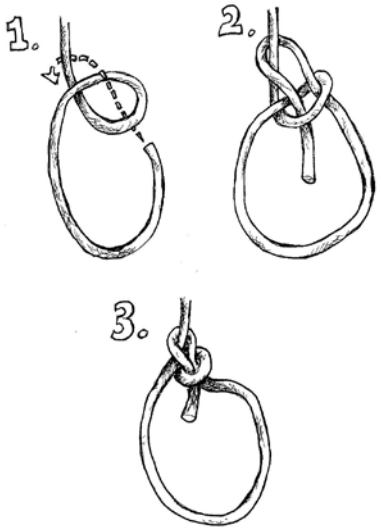
An uncontrolled keeping system is the most risky way to raise livestock. It would be better to move to a semi-intensive system. But if this is not possible, the livestock keeper should build a structure in which to keep the animals at night. This can be a very simple building of local materials, or even a small corral made of local materials. If the animals are given clean water and a small amount of food which they like, or even a salt or mineral block, they will want to come in at night, so it will be easier to find them. Keeping animals contained at night will give the livestock keeper a chance to look at the animals and check them for injury.

Semi-intensive and Intensive Keeping Systems

Semi-intensive systems help to keep the animals safe from predators and thieves, because they are being watched, or confined. However, they can still be injured or poisoned.

Strangling and rope burns

In systems where animals are tethered with a rope around the neck, it is easy for them to strangle themselves if they get over excited or frightened. Tie no-slip knots (See *Where there is no Animal Doctor* by Hesperian, Resources page 41) around the neck; these will not tighten or slip, so they can be untied easily. Tie the other end of the rope with a quick-release knot, so that if the animal is strangling, one end can be pulled and the animal can be quickly released.



Observation

The keeper should remain in the area where the animals are tethered, both for security and to loose an animal if necessary.

Rope and line method

Animals will sometimes go round and round a pole or tree until they strangle themselves. To avoid this, peg a rope into the ground at both ends, then tie a second shorter rope around the animal's neck, and to a loop that goes around the line in the ground. The animal can now go back and forth along the ground line, but not get tangled. (Idea from Agrodok 7 "Goat-keeping in the Tropics.")

Poison and trash

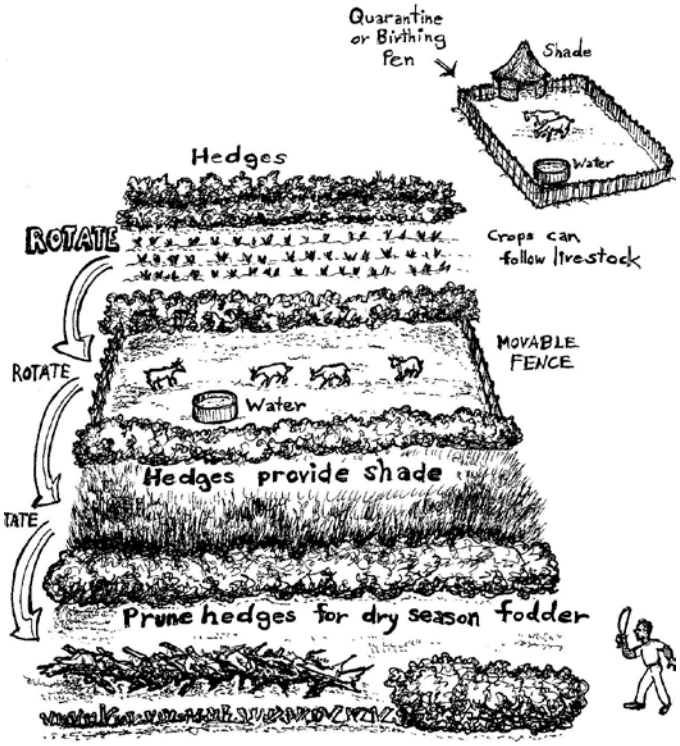
Be sure that the area where the animal is confined or tethered is free of trash and poisonous plants. Goats will readily eat many kinds of trash, which can then get knotted in their stomach and kill them. Plastic bags, especially ones with food or sugary residue, are a big killer of goats.

Cuts

Check the area where the animals are confined for sharp objects that could hurt them. Remove or fix any sharp objects, so that they won't cause harm.

Improve Health

Nutrition and Water: These topics have already been covered. Proper nutrition and hydration help the animal to fight off disease and recover quickly from disease.



Quarantine: Animals who have a potentially contagious disease, or a parasite, should be confined away from the other animals. They should be treated with medicine or local remedies, and should be given plenty of clean water and food.

Rotational grazing: If your animals continue to graze in the same area, they will pick up parasites from each other's feces. However, if the grazing area is rotated every three months, the grass will have a chance to regenerate, and the parasites will die. This is especially effective if all the animals are treated with parasite medicine at the time of rotation.

Local remedies: Many local ways of treating illness are very effective. Ask the people how they treat disease, and use a veterinary book like *Where there is no Vet*, to come up with other ideas. For example, ash prevents skin parasites in chickens, and papaya can be used to treat diarrhea.

Treat Diarrhea: Diarrhea kills animals through dehydration. An animal suffering from diarrhea should be quarantined in a shady area (if it is a baby, its mother should be quarantined with it). Roughage and clean water should be available to the animal at all times. Diarrhea can be caused by parasites, disease, eating trash, or a sudden change in diet. Try to determine the cause. Look at the dung for parasites, look for other symptoms like discharges or coughing which might indicate disease. Was there trash in the area that might have been eaten? Did the animal have access to high-protein food or eat something new? Parasites and disease must be treated or allowed to take their course while the animal is confined. If the animal has eaten trash, there is nothing that can be done, except to wait and see if they get better. If a change in diet is the cause, the animal should recover quickly with a good diet and plenty of water. (See suggested treatment in *Where there is no Vet* or *Where there is no Animal Doctor*).

Shelter and Shade: Providing animals with an optional shelter so that they can get out of bad weather will also help them to stay healthy. Ruminants should be provided with shade wherever they are confined or taken to graze, and they should be given plenty of time during the day to rest in the shade. Nearly 1/3 of a ruminant's time is spent chewing cud. This is a critical process in digestion. Shade is also important to help animals cool down in very hot climates. Note that pigs and poultry cannot sweat, and so overheating can be fatal to them. Pigs should be splashed with water or allowed to wallow in the mud if they are overheating. Chickens can also be splashed with water, or their bedding can be made damp to cool them down.

Nutritional Problems

It is not within the scope of this handbook to fully address nutritional problems. I advise you to see *Where there is no Doctor*, available for free download (see Resources page 41). However, I will make two important suggestions.

Vegetables

Vegetables are higher in nutrients than cereal/staple crops. Vegetable greens generally require less labor than cereal/staple crops to grow, and can be grown in gardens by children, mothers, and the infirmed (all of whom need extra nutrition). Plants that grow for multiple years are called perennials (e.g., chaya). These and multipurpose plants (like amaranth and sweet potato) are especially useful in the home garden. Remember, the darker or more intensely colored the vegetable, the more nutrients it contains.

Moringa

The moringa tree can be effectively used to treat malnutrition. Its leaves are highly nutritious with up to 30% protein on a dry weight basis. They are also high in vitamins and minerals. Mixing green leaves or leaf powder into already cooked meals has a small effect on the taste, but greatly increases the nutritional content. Moringa has been used to kill internal parasites, to cure skin infections (even staph infections), and to help regulate blood sugar in diabetics.

A wild moringa tree, called Teberinto, in El Maisal, El Salvador.

Moringa can also be used as a very nutritious green manure to fertilize plants, or as an important, perhaps even the main constituent, in pig feed. Moringa is fast growing and drought tolerant, and can be grown as a tree, or as a hedge for easier harvesting of leaves. Make sure to dry leaves in the shade to maintain their nutrient content. For more information, go to ECHO's website (see Resources page 41). Look up *Amaranth to Zai Holes* Chapter 4, or ECHO's *Technical Note* on Moringa. Be sure to register with ECHOcommunity.org and, if moringa is not already grown in your area, order a free packet of seed to get started [available to registered active development workers]. (Seeds for many other useful but lesser known food/feed crops are also available.)

Infrastructure Problems

Infrastructure problems affect the distribution, availability and cost of crop inputs and tools, as well as the feasibility of selling a crop. Infrastructure problems affect the ability of a country to develop commercial agriculture or small-scale cash crop production.

Transportation of Crop

Crops grown in rural areas far from urban zones cannot expand their agricultural production without a transportation system to get their goods to town. This requires investment by governments and aid organizations for development of roads. Communities can engage in basic road improvement by maintaining roads and by clearing vegetation to widen footpaths.

Teams of oxen are frequently used to work the land and transport goods in Usulutan Province, El Salvador.

Processing Facilities

Food processing (milling, dehydrating/drying, and canning) add value to a crop, increase its shelf life, and improve its marketability. Processing facilities require an up-front investment to get started. Basic processing can be done in communities. Small portable milling or chopping machines could be purchased by a farming group with small business loans or grants.

Economic Problems

Labor

Subsistence farmers trying to move into cash crop production probably cannot afford to hire labor. One solution to this problem is to form agriculture work groups or cooperatives. Such groups exist in many rural communities, where a work group rotates from farm to farm. Since each person's farm benefits from the work group, the members are not paid.

Cost of Tools/Inputs

The cost of tools and inputs is often very high. Fertilizer, unless subsidized, is often prohibitively expensive. In place of fertilizer, yield improving techniques can be used (see page 13). Encouraging local seed and tool production will lower the cost of inputs.

Credit/Loans

Lack of access to loans is a major problem in most developing nations. Credit institutions can be unstable, prejudiced, or simply non-existent. Loans allow farmers to purchase livestock and needed inputs. With loans, farming groups can also purchase processing equipment to add value to their product. Many NGOs and development organizations offer small loans for business and agriculture projects. However, no farmer should be encouraged to incur loans if a crop failure would cause him/her to lose the farm.

Fluctuating Market Prices, Monopolies

The fluctuation of market prices makes it difficult for farmers to make a profit selling their crop. If the market is volatile, farmers might not plant cash crops, because they might not be able to sell the crop for what they have invested in it. Large companies that own all or most of the businesses (monopolies) engaged in producing supplies, processing, importing, or exporting, can manipulate the market to their advantage. Such problems require national/political action. Information on market pricing is critical for helping farmers decide when to plant and when to sell. In many places, farmers can join a local service to receive daily text messages about market prices. Informally, farmers can also ask friends who live near markets to text them the market prices.

Political/National Problems

Land Availability

In many ways, access to land for farming means access to survival. Land issues are different in every region. In some places, land is taken up by large businesses or private landowners, and little is available for subsistence farmers. In other places, a large population means there is not enough land available for farming. In yet other places, land is held communally and village elders assign land to people who wish to farm. Conflicts and wars can result from unresolved land disputes (see Urban Agriculture page 29).

Political Instability

When nations are going through conflict and instability, agricultural production drops. Farmers are afraid to invest in crops that might be looted or destroyed, or they are unable to plant crops because they must flee. Food aid is critical during times of conflict. After prolonged conflicts, seed and livestock must be brought in to restore production.

Demonstration/Teaching Garden

See Agrodok 9: “The Home Garden in the Tropics” available for free download (see Resources page 41).

Before you start, keep in mind...

- Demonstration is best done by local farmers on their own land.
- All techniques should be able to be applied by the average farmer.
- Consider what is locally available and culturally appropriate in terms of supplies and crops.
- New techniques should be shown alongside traditional techniques.
- There should be a composting demonstration.
- You will need labor to tend the garden (even on school holidays).

A demonstration garden with moringa trees in the foreground in Renk, South Sudan.

Choose a site...

- Near a water source
- With good quality soil, (see Assessing Soil Health on page 10)
- In full sun
- Not too steep and not where it will be flooded

Size of the Garden

- Consider your available labor, available land, and desired yield.
- Yield Approximation (Agrodok 9):
- Leafy vegetables: 8kg/m^2/year
- Fruit vegetables: 10kg/m^2/year
- Fruit (fruit trees): 2kg/m^2/year

Set up your Garden

- **Fence:** You will want to fence your garden to discourage casual thieves, destructive livestock, and wild animals. Use local materials (e.g., living fences, hedges, or commonly used materials) instead of expensive fencing materials. This shows that expensive inputs are not required to make a garden.
- **Clear the ground:** Slash down the weeds and brush, and set it aside for compost or mulch.
- **Compost:** Use the materials you just cleared, as well as nutrient rich additions like crop residue, legume leaves, and manure, to make compost for your garden (see Compost, page 14).
- **Till:** Till your garden using a hoe, pick ax, or shovel, according to what breaks the soil up easiest. You may want to try reduced tillage techniques in part of the garden (see page 24).
- **Design:** Lay out your planting pattern so that there is room to demonstrate different techniques next to each other. (e.g., mulching of eggplant next to traditional farming of eggplant).
- **Perennials:** To set a good example and to have food in production most of the time, be sure to include several kinds of perennial vegetables.
- **Seed beds:** When the soil is loosened, it can be formed into planting beds or furrows. If it is the dry season, you will want to plant at the bottom of furrows or in holes (see Drought, page 24). If it is the rainy season and flooding is a possibility, use raised beds or mounds (see Flood, page 28).

Seed production in a demonstration garden in Usulutan province, El Salvador.

- **Planting:** Plant your seeds directly in the field, or start them in a shaded place and transfer them to the field. Plant seeds at the recommended depth for that seed (too shallow and the seed dries out before it germinates; too deep and the seedling isn't strong enough to break through the soil). If the seedlings are wilting in the sun, they may need to be shaded (see Shade page 26).
- **Timing:** Stagger planting times so that your harvest lasts longer.
- **Irrigate:** Irrigation systems and water saving techniques require some infrastructure set up, which is easier done before the plants begin to grow. See "Drought" (page 24).

Maintenance

- Water as needed, and according to your demonstration plan.
- Remove weeds and their roots before they set seed.
- Weeds can be composted or used as mulch.
- Pest control (see Pests, page 20)

Techniques to Demonstrate

- Mulching (page 13)
- Compost (page 14)
- Cover crop or interplanting crops with legumes (page 15)
- Plant a border of pest repellent/trapping plants, and leguminous trees for mulch production and to encourage biodiversity of insects (see Alley Farming, page 16 and Pests, page 20)
- Plant a variety of locally acceptable vegetables and trees
- If dry (see Drought, page 24): Mulch, zai holes, planting in furrows, tin can drip irrigation.
- If flood potential (see Flood, page 28): Drainage ditches, planting in mounds, raised beds
- If on a slope (see Erosion page 23): Contour planting with hedges, mulch.
- If infested with pests, test different natural pesticide recipes
- Where appropriate, demonstrate and practice seed saving techniques

Use your Garden

Use your garden as a teaching site: Give tours, hold workshops, teach classes, train trainers.

The Harvest

- Use the harvest to feed children at the school/ orphanage/community
- Have the participants split up the harvest
- Sell the harvest and divide the money among the laborers
- Be sure to save some of the seed from the harvest to plant the next crop.

Resources

The information for the writing of this booklet came from the research and writing of ECHO and Agromisa, and other tropical agriculture publications (cited where appropriate); from my personal experiences doing agriculture work in South Sudan, Liberia, and El Salvador; and from studying at the ECHO demonstration farm.

Books

Livestock/Veterinary:

- *Where there is no Vet* by Bill Forse, Published by MacMillan, available from Amazon.com
- *Where there is no Animal Doctor*, Published by Hesperian foundation, available to purchase at: http://www.hesperian.org (use the site search function, enter this title as an exact quote, or search under "Publications" "Books from Other Publishers").

This booklet takes a basic, hands-on approach. If you are looking for a more **scientific approach**, (i.e., texts for educating college students), I highly recommend:

- *The Tropical Agriculturalist* series – By MacMillan Press, approximately 30 topical volumes in print. You can find some titles on Amazon.com, but not reliably. I recommend the ECHO Bookstore (see ECHO information, next)
- Other great books available from ECHO Bookstore online (info next)
- *Longman Intermediate Tropical Agriculture Series* – Difficult to find, mostly out-of-print high-level scientific texts.

Featured Resources:

ECHO – Educational Concerns for Hunger Organization

ECHO has a demonstration farm in Florida and an excellent library and bookstore. ECHO also has two regional impact centers (one in Thailand and one in Tanzania) and organizes occasional regional conferences and symposia. ECHO has the best selection of tropical agriculture books available (books that even Amazon doesn't have). Their bookstore is available online. They also have many free publications online, including their book *Amaranth to Zai Holes: Ideas for Growing Food under Difficult Conditions*. ECHO has a seed bank of excellent crops for development, and will ship free sample packets to development workers. ECHO's staff of expert agriculturalists is available by email or phone to discuss problems and options.

Note: ECHO does significant work with moringa and can provide you with seed and information (see *Technical Notes* on their website).

Build your digital library: Download *Amaranth to Zai Holes*, *Technical Notes* and issues of *ECHO Development Notes*, so that you have access to them even when the internet fails! If you don't have a computer of your own, save them to a flash drive.

Visit ECHO: If you are planning on doing agricultural development work, and you are able to travel to the United States, plan a study trip to ECHO in Ft. Myers, Florida, for at least a week. Their work/study program is very affordable. Also register with ECHOcommunity.org to receive free moringa seeds and other benefits!

Website: www.ECHOcommunity.org **Email:** echo@echonet.org **Phone:** (239) 543-3246

Agromisa (publishes Agrodok)

This group produces handbooks on tropical agriculture for the subsistence farmer, written with practical application in mind. You can request to have Agromisa send these Agrodok handbooks to you for free if you are a development worker with an address in a developing country, or you can purchase them from the ECHO online bookstore. You can also download the handbooks at the website below under the heading "Publications". In the search query, only limit the search by language, to get a list of all available titles in the order of their publication number (listed here with the title name). Note: the website appears to rotate which titles are available for download.

Question and Answer Service: You can submit in-depth questions about issues you are facing in the field, and volunteer experts will research and find answers for you (allow 2 months for answers). Submit a question at their website under the "Question and Answer" heading.

Build your digital library: Download all applicable titles to your computer or flash drive.

Website: www.agromisa.org **Email:** agromisa@agromisa.org

Agrodok series available for FREE download on the internet

(Each handbook has an issue number and a title, listed below.)

Crops and Forestry

- 16 Agroforestry
- 19 Propagating and planting trees
- 5 Fruit growing in the tropics
- 40 Small scale mushroom cultivation
- 41 Small scale mushroom cultivation
- 37 Small scale seed production
- 39 Non-timber forest products
- 10 Soya and other leguminous crops
- 17 How to grow tomatoes and peppers
- 9 The home garden in the tropics
- 22 Small scale production of weaning foods

Agricultural Methods

- 8 Preparation and use of compost
- 28 Identification of crop damage
- 11 Erosion control
- 23 Protected cultivation: greenhouses
- 30 Non-chemical crop protection
- 29 Pesticides: compounds, use, and hazards
- 43 Rainwater harvesting for domestic use
- 2 Soil fertility management
- 13 Water harvesting and soil moisture retention

Livestock/Fish/Bees

- 42 Bee products
- 32 Beekeeping in the tropics
- 14 Dairy cattle husbandry
- 35 Donkeys for traction and tillage
- 33 Duck keeping in the tropics
- 44 Ethnoveterinary medicine
- 21 On farm fish culture
- 15 Small scale freshwater fish farming
- 7 Goat keeping in the tropics
- 34 Hatching eggs by hens or in an incubator
- 1 Pig keeping in the tropics
- 4 Small scale chicken production
- 20 Backyard rabbit farming in the tropics
- 27 Establishing and managing water points for livestock

Post-Harvest

- 31 The storage of tropical agricultural products
- 36 Preparation of dairy products
- 18 Protection of stored grains and pulses
- 12 Preservation of fish and meat
- 25 Granaries
- 3 Preservation of fruit and vegetables

Other topics

- 38 Starting a cooperative
- 26 Marketing for small scale producers
- 45 Mitigating the effects of HIV/AIDS in small scale farming
- 24 Urban agriculture
- **Posters:** Nutrition, natural pesticide recipe, plant tea fertilizer recipe, how to make an efficient stove

Food and Agriculture Organization of the United Nations (FAO)

The FAO is a critically important website. It has indepth agriculture and environmental statistics available for most countries. It also has important news, technical articles, and program information.

Build your digital Library: Look up statistics for your country to see what crops are grown, and what some of the issues are. This will guide your research. Save important reports to your computer or flash drive.

Website: http://www.fao.org

Hesperian Foundation Website

Website: http://www.hesperian.org/publications_download.php

Hesperian has several full books, available for free download

- *A Community Guide to Environmental Health*
- *Where There is No Doctor*
- *Where Women Have No Doctor*
- *A Book for Midwives*
- *A Health Handbook for Women with Disabilities*
- *HIV Health and Your Community*
- *Helping Children Who Are Deaf*
- *Helping Children Who Are Blind*
- *A Worker's Guide to Health and Safety*
- *Cholera Prevention Fact Sheet*
- *Sanitation and Cleanliness for a Healthy Environment*
- *Water for life*
- *Pesticides are poison*
- *Safe Handling of Health Care Waste*
- *Women's Health Exchange*
- *Global Health Watch*
- *Where There Is No Dentist*
- *The Story of Stuff with Annie Leonard*

Spanish

- *Donde no hay doctor*
- *Donde no hay doctor para mujeres*

- *Un libro para parteras*
- *Un manual de salud para mujeres con discapacidad*
- *Ayudar a los niños ciegos*
- *Ayudar a los niños sordos*
- *Donde no hay dentista*
- *Salud laboral en la maquila: Una guía para los trabajadores*
- *Cómo prevenir el Cólera*
- *Saneamiento y limpieza para un ambiente sano*
- *Agua para vivir Cómo proteger el agua comunitaria*
- *Los plaguicidas son veneno*
- *¡Saludos!*

Appropedia

An online user-edited encyclopedia on development and appropriate technology.

Website: http://www.appropedia.org/

All other Resources

Online Libraries and Institutions

International Institute of Tropical Agriculture (IITA) is an Africa-based international research for development organization.

Topics of Research: Agriculture and health, Agro-biodiversity, Banana and plantain systems, Cereal and legume systems, High-value products, Opportunities and threats, Root and tuber systems

Excellent online library of research journals on all topics

Website: http://www.iita.org

CGIAR Consultative Group on International Agricultural Research

This is a major tropical agriculture research organization, with 15 centers around the world.

Website: http://www.cgiar.org

CIAT – International Center for Tropical Agriculture

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

- Libraries: http://www.ciat.cgiar.org/biblioteca/index.htm
- Sustainable Tree Crops Program: http://www.treecrops.org/
- Publications: http://www.ciat.cgiar.org/downloads/ onlinepublications.htm

Royal Tropical Institute (KIT) (The Netherlands)

The aims of KIT are to contribute to sustainable development, poverty alleviation, and cultural preservation and exchange. Publications on issues for the tropics (especially health and economic issues for the developing world)

Libraries: Online Library with broad search topics

Website: http://www.kit.nl

Food & Fertilizer Technology Center (Taiwan)

Information center for farmers in Pacific Asia region. Libraries- tropical agriculture publications (mostly Asian agriculture)

Website: http://www.fftc.agnet.org/library

University of Hawaii Manoa Science & Technology Department

Tropical Agriculture Internet Resources: Libraries- information on agriculture in the tropics, crops, animals, and forestry

Website: http://www.hawaii.edu/sciref/tropag.html

International Rice Research Institute (Philippines)

Publications, research, scholarship opportunities related to rice production

Website: http://www.irri.org/

Belize Development Library on Tropical Agriculture

Website: http://ambergriscaye.com/BzLibrary/ag.html

Sustainable Agriculture

Asian Rural Institute

Trains rural leaders from around the world with the aim of encouraging self-development of communities. It is located in Japan, and students come with a focus on Africa and Asia. See their website for application and scholarship requirements.

Website: http://www.ari-edu.org/en/

Sustainable Agriculture in Hawaii

Sustainable Agriculture (crops, forestry, and animal production) books and articles available for free download.

Website: http://www.ctahr.hawaii.edu/sustainag/newFarmer/links.asp

Center for Agroecology and Sustainable Food Systems

Exploring Sustainability in Agriculture: An Online Sustainable Agriculture Instructional Resource (Santa Cruz, California)

Website: http://socialsciences.ucsc.edu/casfs/-old_site_files/ instruction/esa/

Publication on organic farming and gardening skills, applied soil science, and social and environmental issues in agriculture.

Website: http://repositories.cdlib.org/casfs/tofg/

International Federation of Organic Agriculture Movements

Training manual on tropical organic production methods (available for download or purchase). Topics include organizing training courses; principles of organic agriculture; soil fertility; plant nutrition; pest, disease and weed management; animal husbandry; and farm economy.

Website: http://www.fibl.org/english/publications/training-manual/ content.php

United Nations Conference on Trade and Development

Organic Fruits and Vegetables from the Tropics: publication on how developing countries can enhance their production and export capacities in organic agriculture.

Website: http://www.unctad.org/en/docs/ditccom20032_en.pdf

Soil Health

Soil Food Web Australia

Information on improving soil health, Composts, etc.

Website: http://www.soilfoodweb.com.au/

World Wide Portal to Information on Soil Health

Library on Soil Health information.

Website: http://mulch.mannlib.cornell.edu/browse.html

Pest Control

Recipes for homemade natural pesticides:

- Website: http://www.ghorganics.com/page14.html
- Publications available from the Agromisa website: Agrodok 30 "Non-chemical crop protection," Agrodok 29 "Pesticides: Compounds, use and hazards" and Agromisa Poster: "How to make a Natural Pesticide."
- ECHO's publication "FAITH Gardening."
- Appendix 1 page 47.

Funding / Grants

Sources of Funding

A selection of websites for foundations, donors and other sources of funding from CGIAR.

Website: http://www.ciat.cgiar.org/biblioteca/donors.htm

The Foundation Center

A good primer on applying for funding.

Proposal Writing Short Course, http://foundationcenter.org/getstarted/ tutorials/shortcourse/index.html

Website: http://foundationcenter.org/

References

Gibbon, D. and Pain, Adam. Crops of the Drier Regions of the Tropics. Intermediate Agriculture Series. Logman, London. Pp. 12, 18-19.

All other references referred to in this booklet are detailed in the Resources Section, above.

Appendix 1: Home Pesticide Recipes

(From “Food Always in the Home Gardening” published by ECHO.)

Robin Denney strains a homemade soap, garlic, and oil pesticide concentrate, during a workshop in Kajo Keji, South Sudan.

Ammonia

- 1 liter of water
- 150 ml ammonia
- 1 teaspoon liquid soap

Aphids, flea beetles, scales, thrips, white fly, mealy bug

Citrus Peel

- Mix the grated peel of an orange, lemon, and lime, boil for a few minutes
- Let sit for 24 hours

Potato beetles, caterpillars, other

Clay

- Make a suspension of fine clay in water

Aphids

Flour

(apply in the early morning)

Recipe 1

- 5-10 Liters of water
- + 2 cups (500mL) fine white flour
- + 1 Tablespoon liquid soap

Mites, aphids

Recipe 2

- 50 liters of water
- 250 mL (1 cup) sour milk
- 8 cups (2 liters) fine white flour
- 250 mL (1 cup), liquid soap

Aphids (kills), mites, thrips, white fly

Recipe 3

- dust flour on leaves to control caterpillars

Garlic

- 1 liter of water
- 2 mashed garlic cloves
- let steep for 24 hours

Aphids, spider mites, scale

Garlic Oil

- mash 20 cloves of garlic, cover with oil,
- let sit 24 hours
- Save the oil
- Mix 2 teaspoons of the garlic oil in 500mL of water + liquid soap
- Dilute again, 2 teaspoons of mixture in 500mL of water

Larger insects, leafhoppers, slugs, plant bugs, whitefly

Garlic Oil and Pepper

- mash 10 cloves of garlic, cover with oil,
- let sit 24 hours
- Add 1 liter of water + 10mL of liquid soap
- Boil 5 hot peppers in 2mL of water until the water reduces by half
- Add pepper water to garlic/oil/water mixture

Kerosene

- 4 liters of water
- 3 Tablespoons of kerosene
- ½ teaspoon liquid soap
- Mix well and shake constantly while spraying

Powdery mildew, various insects

Marigold

- chop leaves, fill 2 cups
- pour 1 liter boiling water over chopped leaves
- let steep 24 hours

Aphids, caterpillars, fleas on dogs

Milk

- 4 liters of water, +2 cups of milk
- OR as strong as ½ water ½ milk

Fungicide

Neem Leaf

- 5 liters of water
- 1 kilo of neem leaf
- soak overnight; grind the soaking leaves and filter the extract
- 1 teaspoon liquid soap

Neem Seed

- crush 500g neem seed (3 double handfuls) in a mortar, into a paste
- mix thoroughly in 10 liters of water
- let soak overnight
- filter

Diamond back moth, cabbage worm, aphids, cutworms, locusts, lacebug, armyworm, flea beetle, green rice leaf hopper, jassids, leaf miners, mites, nematodes, stalk borer, tomato leaf spot fungus

Pepper (hot pepper)

Recipe 1

- 1 liter of water
- 1 teaspoon liquid soap
- pinch of dried hot chili powder

Recipe 2

- Chop, and mash:
  - 3 hot peppers
  - ½ onion
  - 1 garlic clove
- Mix in 1 liter of water
- Let steep 24 hours
- 1 teaspoon liquid soap

Aphids, scale

Soap

- 4 liters of water
- 5 teaspoons liquid soap

Aphids, thrips, caterpillars, whiteflies, mites, slugs, leaf miner, beetles (use stronger solution for stronger insects)

Tomato Leaf

(Do not use on tomato, potato, pepper, eggplant.)

- 2 liters of water
- 1 kilo chopped tomato leaves and stems
- bring to a boil
- allow to cool, add 2 teaspoons liquid soap

Repels caterpillars, flies, aphids, cockroaches, moth, grasshoppers, grubs, larvae, nematodes, mites, tomato hornworm, fungi, bacteria wilt

About the Author

Robin Denney received a BSc degree from the University of California, Davis, College of Agriculture and Environmental Sciences. She grew up on a farm in California working with livestock and growing crops. She has experience working in commercial agriculture in California and Australia, and in agriculture policy for the state legislature.

She worked for two and a half years in South Sudan, where she helped the Episcopal Church of the Sudan to develop pilot farms and agriculture training programs. She also served for a year in Liberia as a member of the Episcopal Young Adult Service Corps, teaching and designing agriculture and livestock programs and curriculum at Cuttington University. She has done short-term agricultural mission work in El Salvador and Tanzania. She has also trained missionaries and given workshops domestically on sustainable agriculture and faith and agriculture.

Acknowledgements

Thank you to Dawn Berkelaar and Martin Price for editing, to Cody Kiefer for formatting the document, to Larry Yarger and Bob Hargrave for their suggestions, and to everyone at ECHO. Thank you to Rev. David Copley and the Episcopal Church Mission Personnel Office for all their support, and to Cuttington University in Liberia, Iglesia Anglicana de El Salvador, Bishop Gwynne College in South Sudan, and the Episcopal Church of the Sudan for helping to form this publication. Thank you to Mary Wharton for the great illustrations in this document.