



Taking Action

Reaching Out

Agroforestry Training Program

Third Edition

Taking Action Reaching Out

A Publication of



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Preface

Expansion of agricultural land and a variety of human activities have led to deforestation and land degradation in many parts of the world. If this continues, the potential contribution of forests to economic development and ecological stability will not be realized. Developing new natural resource management techniques to address such devastating environmental degradation is important for our rapidly growing world. The lack of training materials for land management, reforestation and agroforestry in many developing nations makes the problem worse. Field technicians, community leaders, and others need appropriate training aids in sustainable land management for economic development that does not cause environmental degradation.

Trees for the Future was launched three decades ago to address issues of deforestation and environmental degradation. Since then, Trees for the Future has planted over 50 million multipurpose tree species and has assisted in transferring real life experience and technology about reforestation efforts. We at Trees for the Future believe that agroforestry technologies are important for addressing problems in developing countries. Agroforestry is a collective name for land use systems that combine trees with crops and/or animals on the same unit of land. We are developing new and innovative learning materials to train individuals in agroforestry, but it is difficult to reach them because the majority does not have access to the internet, computers, and in many situations, electricity. Therefore, to connect the disconnected communities to the rest of the world we are pleased to offer this second edition of Agroforestry Training Manual.

The training manual contains valuable information about our own experience as well as those of communities in Africa, the Americas and Asia where we have assisted people over a period of over 30 years. It begins by outlining the challenges of our time: land degradation, deforestation, and climate change. Next, the manual explains agroforestry as a science and an art, followed by major agroforestry technologies and conservation techniques. Once these basics are covered, the manual outlines appropriate multipurpose tree species for (sub) tropical countries, seed collection and handling methods, and tree propagation and nursery management. We sincerely hope that the training manual will be useful to millions of farming families and forestry practitioners.

The manual does not address all of the challenges of sustainable land management. For the next edition of the manual we would like to hear from you to refine and add to the manual's content. In the meantime, we would like to assure you of our commitment to solve these problems.

We have learned that tree planting and an integrated approach for land management can be a lonely occupation, but it is important work at a time when natural resources are under threat. For this reason, when you have completed this training program, there is a test waiting for you. You will become a graduate and you will possess a certificate of accomplishment so the whole world will know of the importance of your work. After successfully completing this program, we ask that you use it to train others so that the program will never stop growing. We wish you well and hope to hear from you soon.

TREES FOR THE FUTURE
September, 2008



Agroforestry Training Program

Certificate in Agroforestry

This training program contains:

- This *Taking Action Reaching Out* Training Packet
- The Agroforestry Library CD

Using this training packet:

Each of the lessons in this training packet begins with specific objectives. At the end of each lesson, you will be expected to be able to meet those objectives. The final evaluation of this long distance training course is the agroforestry test at the end of this packet. Submission guidelines are located on the inside of the back cover.

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Lesson 1: Sustainable Land Management

Lesson Objectives: By the end of Lesson 1, YOU will be able to: 1) define and explain sustainable land management; 2) list 3 major sources of brush fires; 3) explain why overgrazing occurs; 4) list 3 major concerns with planting too many eucalyptus and pine species; 5) explain how chemical fertilizers and pesticides damage the soil; and 6) list 3 reasons for global deforestation

Increased rates of deforestation, unsustainable agricultural land use, and severe soil degradation are creating widespread poverty and environmental degradation in developing countries (NAS,1993; Swift, 2007). Each day, the world loses about 125 square miles (~320 km²) of its forests, that's 34.5 million acres (14 million hectares) every year (FAO,1996). Most of this takes place in the developing countries of the humid tropics. Reforestation efforts are limited to only about 10% of the total area and most efforts are not promising (Lamb, et al. 2005).

Every year, the equivalent of 40 billion tons of carbon dioxide enters the global atmosphere, the result of the ever-increasing use of fossil fuels. This increase in atmospheric carbon, in combination with the loss of forests has combined to make global climate change worse.

The resulting human tragedy must be a cause for real concern, because it affects all of us in so many ways. Global food security is declining, as is the world's supply of safe drinking water. The death toll from floods and mudslides rises every year. World peace is threatened as nations wage war over a dwindling base of natural resources. Millions of rural families are forced from their homes into urban slums as the loss of the forests makes it no longer possible for their lands to support them.

The adoption of sustainable agriculture is often proposed as a solution to these problems. Sustainable agriculture is concerned with agricultural practices that are economically viable, meet human needs for food, are environmentally friendly, and improve quality of life. Agroforestry is one such land use practice that maintains sustainability at its core.

Deforestation is a major unsustainable land use practice. Yet little is being done to address its economic, environmental and ecological impact (Teketay, 2001). Clear-cut logging, uncontrolled brush and forest fires, and traditional slash and burn agricultural techniques have damaged the environment as well as the agricultural resource base. Additionally, every year, reforestation efforts that intend to help communities are actually assisting in planting the wrong types of tree species, resulting in long-term damage. This concerns all of us, especially the families who rely on trees for the basic necessities of life: fuel, water, food, building materials, and the air we breathe.

Cutting trees is NOT a bad thing. Trees are an important resource for everyone on earth. The problem is when people cut trees but do not replant them. Trees are cut for many reasons. Industries based on construction and making items such as furniture (beds, tables) are always in need of valuable hardwood trees. Wood (sometimes in the form of charcoal) is the major source of cooking fuel for



Pic 1A: Children in Ethiopia carrying firewood.



Pic 1B: Effects of a fire.



Pic 1C: Children herding cattle in the degraded lands of East Africa.

Lesson 1: Sustainable Land Management

over half of the world (FAO,1999). Because populations and industries in every country are growing, there is always a growing pressure on forest resources. Slash-and-burn agriculture, characterized by periodic burning of the land both to get rid of weeds and to use the ash as fertilizer, is also contributing to the rapid loss of the world's forests.

Brush and forest fires (pic 1B) not only inhibit the regeneration of tree seedlings (though some grasses, trees and shrubs have evolved the ability to regenerate after fires), they also destroy what little organic matter remains in the soil. Fires are often caused by smoking and cigarettes, unskilled beekeeping techniques, and uncontrolled burning of fields for cultivation and grazing.

Overgrazing is another major cause of land degradation. Communities all over the world rely on animals for food, fiber, and labor (pic 1C). Herding animals through grazing lands, if done correctly, is a viable way to produce livestock, but it is seldom done correctly (see Lesson 4). There are always too many animals in too little space, trampling the ground and eating all of the vegetation including tree seedlings. While animals do leave their manure in the places they graze (contributing something positive to the soil) the overall effect of overgrazing is highly detrimental. Especially destructive are the grazing habits of goats, whose small lips (unlike those of a cow) can graze a plant or even seedling down to the soil, preventing it from resprouting. Overgrazing also results in soil erosion; stripping the most fertile top soil and with it much of the soil organic matter, further reducing the land's productivity.

Some Trees Cause Long Term Damage!?

In the global program of Trees for the Future, we provide seeds of multi-purpose, fast-growing (MPFG) trees. In order to extend the program into many climactic zones, and to make it more beneficial to the participants, we are constantly looking for promising species, but we approach this with a great deal of care when making recommendations.

Eucalyptus trees grow rapidly into true trees at a wide range of elevations, soils, and climactic conditions. They sustainably produce fuelwood and timber suitable for many local construction needs, and they produce oil used in some medications and other products, BUT . . . **Eucalyptus trees do not lend themselves to sustainable land management systems** (Lisanetwork and Michelson, 1993).

Many communities in Central America, the Caribbean, Africa and Asia are suffering from the long term damage caused by massive eucalyptus plantings. At first, most communities were content with having a tree, which when harvested, grew back as two trees. These became four, and so forth. Throughout each coppicing, the root system, barely under the surface of the soil, continued to widen into fields where farmers once grew crops.

Farmers quickly discovered that eucalyptus trees are causing problems with their roots by taking all available water and nutrients from neighboring trees and crops, and also with their leaves, which blanket the ground inhibiting new growth. Eucalyptus trees inhibit the growth of other vegetation



Pic 1D: Leaves of eucalyptus trees in this shelter-belt in northern Nigeria blanket the ground.



Pic 1E: The lack of vegetation beneath these eucalyptus trees leads to soil erosion.



Pic 1F: Most plants and trees cannot grow in the understory of pine trees because of the 'blankets' of acidic pine needles.

Lesson 1: Sustainable Land Management

(Sasikumar et al. 2001) (pic 1E), exposing soils to erosion, and causing lakes and ground water to disappear with their aggressive roots.

Pine trees (Pic 1F), which are planted throughout much of the world for their valuable timber present a similar problem. Beneath pine trees, you will rarely find a productive understory; you tend to find a blanket of acidic needles that inhibit the growth of everything. The needles are also a great fuel for forest fires. **Pine trees do have their benefits, but like eucalyptus trees, they do not lend themselves to sustainable land management systems.** These trees can leave soils in much worse condition than when they were first planted.

In our program at Trees for the Future, we encourage communities to plant multipurpose fast growing (MPFG) trees that not only produce useful products within a short time, but ALSO encourage the growth of field crops, vegetables, and other vegetation around them.

Water & Soil

Water and soil are two of the most important resources for farming communities around the world. The soil and water of any community MUST be conserved so that future generations will be able to feed themselves. In our work, we see serious soil and land degradation taking place, but we also see some great solutions that address these problems.

Soils form layers called horizons. By digging a hole in the ground, one can easily see the O and A, and possibly the B, horizons (pic 1G). The O horizon consists of organic material on top of the soil. The A horizon is a dark, living layer of soil where organic material and beneficial microorganisms mix with inorganic products (rocks, minerals) of weathering, and the B horizon lies just beneath the A horizon and tends to be lighter in color. While the A horizon in the United States is often several meters deep, the A horizon in most tropical soils is less than a few centimeters.

Many nutrients leach out of this top layer and settle deep in the ground. For these lost

nutrients, it takes trees with strong, deep tap roots to bring nutrients back to the surface through falling leaves. We must take precious care of these top layers of soil because this is where we grow our food. Unfortunately erosion, insecticides, fertilizers, and burning cause serious long term damage to the topsoil layer.

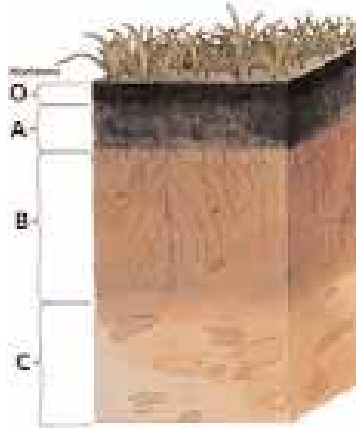
When soils are unprotected, they are easily eroded by wind and water. Because the best soil was on the surface, all that remains are bare fields with few nutrients. Because of soil erosion, we see muddy rivers, cloudy oceans, gullies, mudslides, and dust storms. Much of agroforestry, which we will examine further in Lesson 3, aims to protect soils from heavy rains and strong winds.

Besides these physical processes, we also see chemicals that damage soils; primarily in the form of insecticides and fertilizers. Chemical fertilizers and insecticides are unsustainable, temporary solutions that rarely improve the quality of the soil.

Pesticides often kill many of the insects and microbes in soils that are needed for natural processes. There are, in fact, many beneficial insects that eat many of the pest insects, but most insecticides kill everything indiscriminately. Not only are they poisonous and often improperly used, but some pesticides that are banned from use and sale in the United States and Europe are available throughout the developing world. Furthermore, insecticides get concentrated from smaller insects into the larger animals that eat them, ultimately poisoning the entire food chain. Alternatives to pesticide use entail 1) giving crops the strength they need to resist infestation by adding nutrients and organic matter to the soil, and 2) using Integrated Pest Management techniques that ward off and kill insects (page 30).

Fertilizers also cause long term damage, and are often inadequate in their nutrient composition (ICRAF,1999). Soils need rich organic matter in the form of humus, compost, manure, etc. Commercial fertilizers, often in the form of NPK pellets, contain just nitrogen, potassium, and phosphorous. These are three of the major nutrients, but there are also plenty of other nutrients -

Figure 1G: Soil layers



Lesson 1: Sustainable Land Management

such as manganese, iron, boron, zinc, and copper - that chemical fertilizers tend not to contain. Furthermore, rains can immediately leach these chemical fertilizers down through the soil, contaminating groundwater and forcing farmers to apply more fertilizer every year.

I know insecticides are bad, but how do fertilizers damage the soil?

We often see communities using N-P-K fertilizer in forms such as 10-10-20, 15-15-15, and 20-20-20). These numbers refer to the portions of nitrogen, phosphorous, and potassium in the fertilizer. Chemical fertilizers cause at least 4 major problems in soil and vegetation:

1. Fertilizers kill beneficial organisms that live in the soil. This includes both small microorganisms and larger ones such as earthworms. Chemical fertilizers are often acidic, which causes the pH of the soil to change, thereby harming organisms that are critical to soil health.

2. Chemical fertilizers create hardpans in the soil. Hardpans are hard layers that can form naturally or unnaturally under the soil. While microorganisms and organic matter hold healthy soil together, the chemicals actually break down the soil particles creating a cement-like state, which decreases the soils ability to trap and hold water. Additionally, chemicals applied to crops can seep into surface and underground water supplies, thus contaminating them - a major concern in rural areas of the developing world that lack treated drinking water.

3. Fertilizers can damage plants' health, because a plant's ability to defend itself from bacteria and

fungi is directly related to nutrient amounts in the soil. Large increases in either nitrogen or phosphorous can kill certain beneficial microorganisms that live in the roots of plants, making them more susceptible to injury and diseases. Sudden, large increases in nitrogen levels, combined with a lack of trace elements, have been shown to cause diseases in plants.

4. Plants can experience a deficiency in trace minerals, even if the trace minerals are locally available in the soil. This is because overuse of chemical fertilizers inhibits the chemical and physical reactions that transfer the trace elements into

the plants through the root hairs. This is all very complicated, and is beyond the scope of this training manual to explain, but it is a known fact that the roots of plants can get covered by so many charged particles, such as sodium ions, that they can no longer absorb the other minerals they need.

Green manures are sustainable alternatives to chemical fertilizers. Agricultural crops which received green manure of *Gliricidia sepium* yielded 9.5 tons per hectare of maize in Oromia, Ethiopia. A similar yield was obtained from plots which received green manure of *Leucaena pallida* and *L. diversifolia*, but a significantly reduced yield was obtained from plots receiving recom-

mended levels of chemical fertilizer (Diriba et al, 2002). This implies that the use of multipurpose fast growing agroforestry species as a green manure can boost grain production over levels obtained from chemical fertilizer. Additionally the multipurpose species provide the farmer with fruit, fuelwood, fodder, and construction wood.



Pic 1H: Healthy soil should be dark in color. Though invisible to the eye, this compost (page 28) contains millions of healthy microorganisms. Pesticides and fertilizers destroy this microlife.

Lesson 2: Trees & Global Climate Change

Lesson Objectives: By the end of Lesson 2, YOU will be able to: 1) explain why atmospheric carbon levels are increasing; 2) define climate change; 3) briefly explain the greenhouse effect; 4) list at least 4 environmental problems that have resulted from climate change; and 5) list 3 positive things that trees and forests do to combat the effects of global warming.

Climate change is one of the greatest environmental, economic and social threats facing the globe. The earth has been going through natural heating and cooling cycles, taking place over hundreds, often thousands, of years. Then, starting in the early years of the 19th Century, the warming increased rapidly. The change began to accelerate during the Industrial Revolution, a time during the 1800's when new technology enabled industries to replace animal and human labor with machines driven by fossil fuels. These new machines revolutionized production and transportation, but at a significant cost to the environment.

Like wood and other organic fuels, fossil fuels - such as coal, gas and oil - are composed mostly of carbon. When burned, the carbon unites with oxygen and forms carbon dioxide (CO₂). As industries grew, and the use of fossil fuels increased, so did levels of carbon dioxide in the global atmosphere (figure 2A).

The use of fossil fuels has been increasing for almost 200 years. Now, more than ever, the atmosphere is filled with dangerously high levels of carbon-dioxide. It is colorless and odorless, so we can't see or smell it, but it spreads itself evenly throughout the world; air pollution does not respect international boundaries.

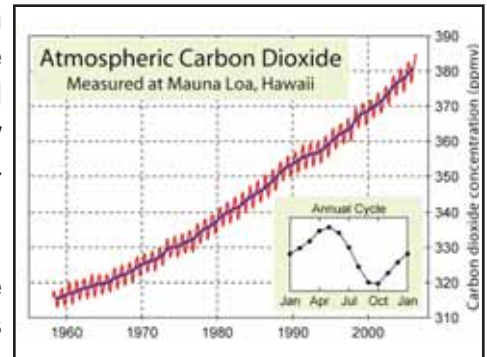


Figure 2A: Carbon dioxide emissions increased rapidly in the last century.

The Greenhouse Effect

Solar radiation from the sun, which we see as light and feel as heat, constantly shines on the earth. Some of the heat is absorbed and some is reflected. Carbon dioxide works like an invisible blanket that wraps around the earth, trapping the heat inside (see figure 2B).

A greenhouse is a structure that is used in colder climates to grow plants, flowers, and vegetables. Even when outside temperatures drop below freezing, greenhouses are still warm enough inside to grow plants. Greenhouses are made of glass, which allows solar radiation to enter. The heat is trapped inside the greenhouse, allowing plants to grow all year around.

Increasing concentrations of carbon dioxide in the earth's atmosphere insulate it like a greenhouse, leading to a gradual warming of the earth's atmosphere. Carbon dioxide is the major greenhouse gas, but there are others as well, including methane and nitrous oxide.

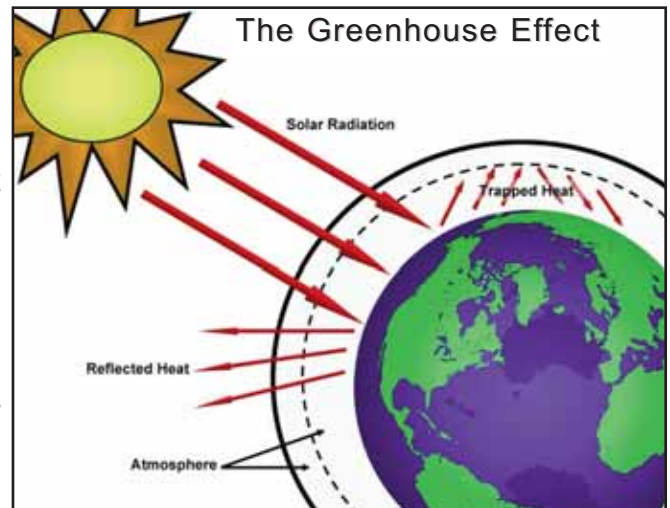


Figure 2B: Carbon dioxide traps heat in the earth's atmosphere everyday, contributing to the Greenhouse Effect.

Increasing Temperatures

Over the last 120 years, the average global temperature has increased by about 1.3 degrees C (see figure 2C). The rate of increase is accelerating and that over this new century, the average temperature will increase by about two (2) additional degrees Celsius.

In recent years, we have seen record temperatures on every continent. Animals and insects

Lesson 2: Trees & Global Climate Change

are changing their migratory patterns. Invasive species and insects such as malaria-carrying mosquitoes are spreading into new territories. Glaciers in the arctic regions, on Mount Kilimanjaro in Kenya, Mount Fuji in Japan, and throughout Europe, Asia, and the Americas, are melting, causing the world's oceans to rise. People in small island nations in the Pacific Ocean have already been forced to abandon their homes.

As ocean temperatures increase, coral reefs die, hurricanes increase in frequency and strength, and weather patterns change. Droughts and floods have become more common than ever before.

The term 'climate change' refers to significant changes in the average weather, such as wind and rainfall, experienced in a region over a long period of time. The climate on earth has naturally undergone many changes in the past. The rate at which the climate has been changing over the past 200 years however; has led to a consensus among scientists that this change is due to human activity. Global climate change is affecting all of us.

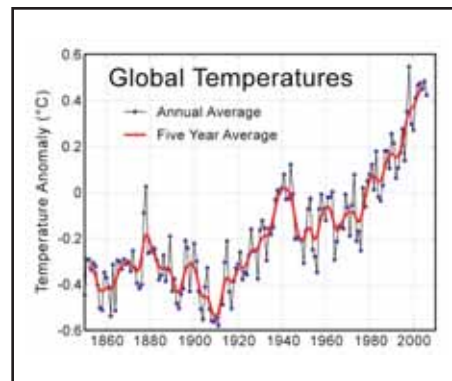


Figure 2C: Average global temperatures are increasing so fast that flora and fauna throughout the world cannot adapt quickly enough.
www.wikipedia.org

Atmospheric Levels of Carbon Can Be Brought Down

Through a natural process called photosynthesis (figure 2D), plants remove carbon dioxide from the atmosphere and release oxygen. They store this carbon in their leaves, branches, trunks, and roots. Because trees grow faster in the tropics, they absorb more carbon than trees in temperate regions.

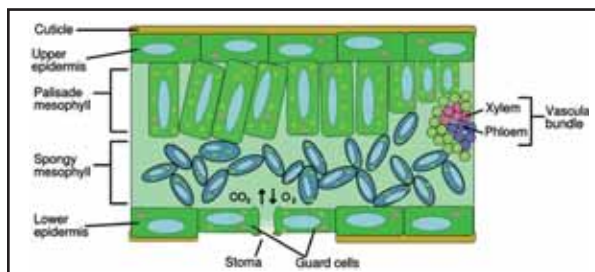


Figure 2D: Through photosynthesis, trees remove CO₂ from the global atmosphere.
www.wikipedia.org/wiki/leaf

An average tree in our program can remove about 50-53 lbs (23 kg) of carbon dioxide from the atmosphere annually. In agroforestry projects, where trees encourage the growth of other vegetation in their understory, the amount of carbon sequestration is further increased.

The Importance of the World's Forests

Forests are critically important carbon warehouses that filter massive quantities of carbon from the atmosphere, trapping it in their biomass (Roshetko and Lasco, 2008). The Food and Agriculture Organization of the United Nations estimates that the world's forests store 283 gigatons (Gt) of carbon in their trunks and roots. Additionally, there is more carbon stored in the deadwood, leaves, and soil of forests than there is in the earth's entire atmosphere (FAO, 2006).

Deforestation has caused the deaths of thousands upon thousands of people. Mudslides and floods that result from the loss of tree cover are happening more and more frequently. Despite the common belief that clearing an area prevents the spread of malaria, it has now been shown that because forests also contain bats, birds, and other enemies of mosquitoes, deforestation actually increases the prevalence of malaria carrying *Anopheles* mosquitoes.

The increased use of fossil fuels is only one part of the threat of Global Climate Change. With it, the earth is losing its forests at a rate of 14 million hectares every year (FAO, 2006). As lands are cleared, they are also burned; releasing even more carbon into the atmosphere with fewer trees to remove it. Introducing all this formerly-stored carbon into the atmosphere, with no corresponding mechanism to take it back out, has also contributed to the current high levels of CO₂ in the atmosphere. Clearly one part of the fight against climate change must include re-establishing global forest cover.

Lesson 3: Agroforestry Technologies - Introduction

Lesson Objectives: By the end of Lesson 3, YOU will be able to 1) define agroforestry; 2) distinguish major agroforestry classification schemes; 3) list 4 keys to success in extending agroforestry, and, 4) after studying pages 8-20, identify and explain the agroforestry technologies most appropriate for your region and the communities you serve.

Agroforestry is a land-use system that integrates trees (woody perennials), crops, people, and/or animals on the same piece of land in order to get higher productivity, greater economic returns, and more social benefits on a sustained basis (Huxley and van Houten, 1997). This can be done by planting trees and crops together in the same field at the same time, or they can be planted one after the other. Agroforestry provides an alternative land use model, that is a potential solution to address land management problems.

Researchers at the World Agroforestry Centre found that for every hectare put into agroforestry alternatives, five to ten hectares can be saved. By planting the correct trees on their lands, farmers can improve the quality of their farmlands, develop income generating opportunities, and they can establish sustainable supplies of high-protein animal forage, fuelwood, food crops, and organic fertilizer. Trees in these systems provide valuable goods and services, including human food and forage for animal production, natural fertilizers and tools for agricultural production, cash crops for economic development, fuelwood, construction materials, physical protection for agricultural fields, and soil conservation. Agroforestry is not only a science, but also an ancient, widely-used practice that cultivators have engaged in the world over.

Agroforestry is important for all climactic zones. Not only does agroforestry provide useful and marketable products, it diversifies the timing of production so that farmers do not receive their entire year's income at one time. It can improve the yields of agricultural systems, while also diversifying the products from the system. Ultimately, the use of agroforestry leads to food security, soil and water conservation, and long-term sustainable agriculture.



A forest garden in Mali

What are the five (5) keys to a successful agroforestry program? (see Lesson 6)

1. Gather information about practices in your area and then to tailor your work to meet local needs.
2. Local people must be willing to cooperate and participate.
3. The program must be sensitive to cultural practices, especially traditional patterns of land tenure, land use, and vegetation use.
4. The agroforestry program must be technically sound and climactically appropriate.
5. It must provide useful products and be economically viable, building self-reliance rather than dependence on expensive materials.



A living fence in Senegal

Lesson 3: Agroforestry Technologies - Introduction

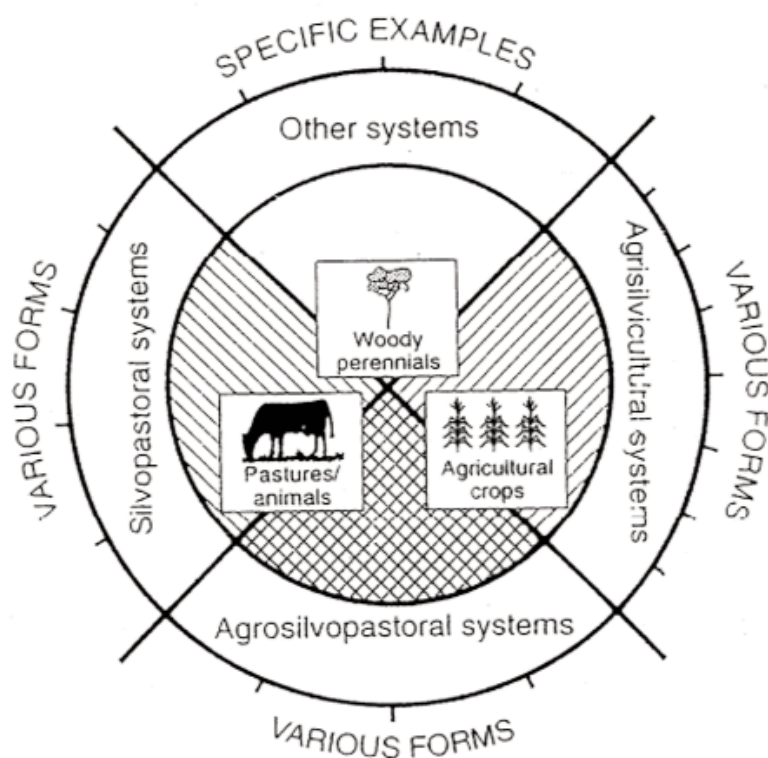


Figure 3A1. Classification of agroforestry systems based on the type of components.

Agrisilviculture - crops (including shrubs/vines) and trees.

Silvopastoral - pasture/animals and trees

Agrosilvopastoral - crops, pasture/animals and trees.

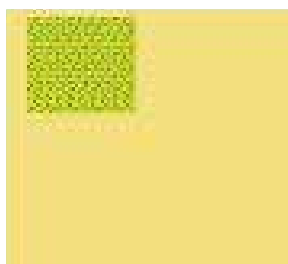
Source: Nair (1993)

Both time and space are important management components in agroforestry systems. Figure 3A1 shows ways of classifying these systems based on the main components (crops, animals, and trees), while figure 3A2 shows different ways that trees are placed in agroforestry systems.

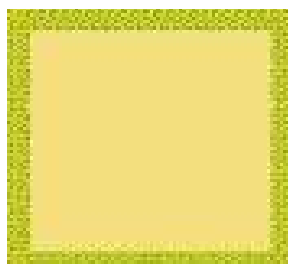
In these systems, the density of planting varies from dense (as in forest gardens, windbreaks, and living fences) to sparse (as when trees are planted in pastures). This spatial arrangement can change over time. In rotational fallow systems, crops are grown for 2-3 years, which is followed by more than 15 years when trees are allowed to regrow naturally. However, this requires large amounts of land to be left alone for many years, which is not possible in many areas.

Agroforestry supports sustainability in two key ways. First, agroforestry systems are designed to yield beneficial products that meet the farmers needs, and secondly they serve to protect and maintain the production of this system by reducing wind and water erosion, improving the health of the soil, and increasing water infiltration.

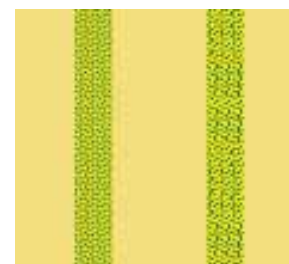
Spatial Arrangement of Trees in Agroforestry Systems



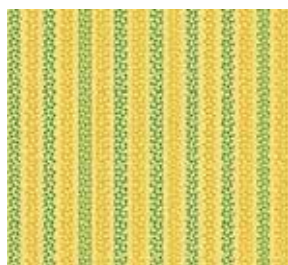
Rotational Fallow



Boundary Planting



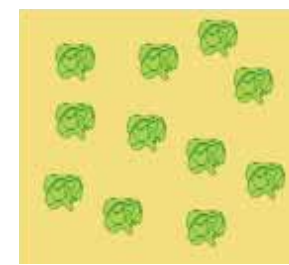
Windbreaks



Alley Cropping



Trees in Cropland (large scale)



Trees in Cropland (small scale)

Figure 3A2. Spatial arrangement of trees in Agroforestry systems

Lesson 3: Agroforestry Technologies - Windbreaks

Enabling Objective: By the end of studying this page, YOU will be able to describe the orientation, design, and make-up of a windbreak.

Windbreaks are one of many agroforestry technologies that increase overall productivity of land and environmental quality. Windbreaks incorporate many useful multipurpose species and management practices that will return additional income to the producer.

Purpose and Design:

Windbreaks slow the wind at crop level and divert the force of the wind to higher altitudes. Farmers plant windbreaks for four main reasons:

- 1) to minimize damage to vegetables and crops
- 2) to protect vegetables and fruit trees while they are flowering (because fruits and vegetables develop from the flowers, you can increase production by protecting the flowers from heavy winds)
- 3) to minimize soil erosion
- 4) to minimize the amount of moisture the winds evaporate from soils

The species composition of trees and shrubs used in windbreaks vary greatly around the world, but the basic design of windbreaks stays the same. There tends to be a time of the year, often during the dry season, when strong winds cause the most damage. It is those strongest winds which must be addressed first.

Windbreaks should be planted perpendicular to the wind. It may be necessary to plant windbreaks on multiple sides of fields because the wind often changes direction during the year. Communities can work together, analyze their farmlands, and identify major areas where massive windbreaks can be established to benefit the entire community, OR individual farmers and families can create smaller windbreaks on their own individual plots (pics 3B1 & 3B2). Large windbreaks can extend for many kilometers and can benefit many communities, while the smaller windbreaks can be planted around single fields for the benefit of single families - all projects are different.

Desirable characteristics of windbreak species includes: ability to withstand strong winds, deep spreading root system to add stability to the windbreak by making the trees less susceptible to wind

Pic 3B1: Prosopis trees in this windbreak shed large amounts of small leaflets that quickly break down and add nitrogen and other nutrients to the soil.



Pic 3B2: Farmers visit a field surrounded by a 2-year old windbreak made of leucaena and prosopis trees.



Can you design the orientation and make-up of a windbreak?

Lesson 3: Agroforestry Technologies - Windbreaks

damage, and trees with small open crowns which reduces the risk of wind damage.

Figure 3C shows why the windbreak must not be too dense; the goal is to slow the wind down, not to stop it. By creating a windbreak that is too dense, winds will actually come crashing over the windbreak, causing damage to the field. Windbreaks can protect for a distance of up to ten times the height of the tallest trees, so 5 meter tall trees protect fields for 50 meters - as long as the windbreak is uniform in height and spacing among trees.

To better understand the design of a windbreak, we will have to examine it from the top and side (figures 3D and 3E): From a side view, windbreaks should be shaped like the letter "A". If you look at figure 3D, the tall trees in the middle of the windbreak stand between rows of shorter bushes. By integrating tall trees, short trees, bushes, and grasses into the windbreak, you can protect from winds at all levels and you can diversify the products that you can harvest from it. Keep in mind that it is usually not recommended to plant fruit trees in windbreaks because the stress from winds will keep them from producing much fruit, with the exception of tamarind trees, those in the genus *Averrhoa*, and those that develop fruit along their trunk, not on the ends of their branches.

Windbreaks can be single lines of trees, though it is best to have two or more rows. The lines of trees should be staggered, as shown in (figure 3E). In picture 3i (p.13), it is difficult to see, but the seedlings have been planted in staggered lines as shown in figure 3E.

A major problem to avoid is funneling (figure 3F): When windbreaks have gaps in them, the wind is channeled into those gaps, creating a destructive tunnel of high winds that can destroy crops.

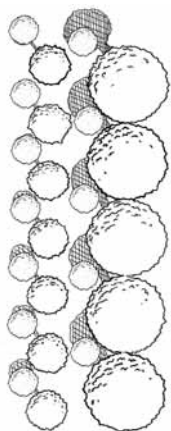


Figure 3E: Stagger the rows by planting trees to fill the spaces between trees in other rows.

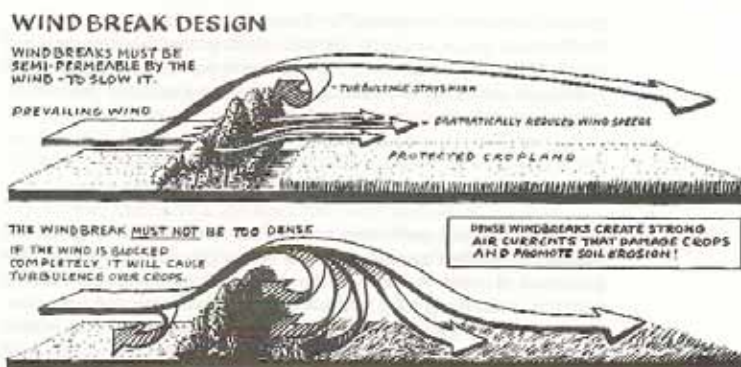


Figure 3C: Windbreaks must not be too dense. When you look through the windbreak, you should be able to see 60-80% foliage. Agroforestry in Dryland Africa, ICRAF

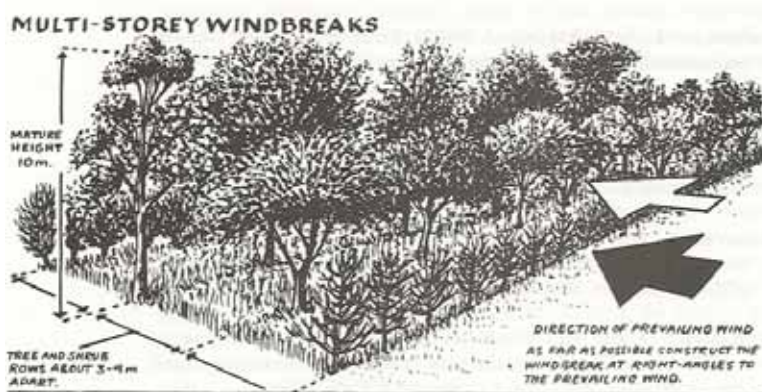


Figure 3D: From a side view, the windbreak should have the shape of an "A." Shorter bushes and grasses should be on the front and back, and taller trees should be in the middle. Windbreaks protect fields for a distance of 10 times the height of the tallest trees. Agroforestry in Dryland Africa, ICRAF



Figure 3F: Openings in a windbreak can cause the winds to funnel. These gaps can cause damage to crops.

Lesson 3: Agroforestry Technologies - Living Fences

Enabling Objective: By the end of this page, YOU will be able to 1) describe the desirable characteristics of trees useful for live fence and 2) design & maintain a living fence.

Purpose: A living fence is an animal-proof barrier composed of trees and shrubs planted at close spacings around the perimeter of a field. Not only do living fences reduce the need (and cost) for standard fencing, but the trees and shrubs utilized in living fences can produce tangible benefits such as food, fuelwood, fodder, and other raw materials. Families who normally pay others to build fences see a major savings in never having to pay anyone to construct or fix their fence - but this is not to say that maintaining a living fence is *not* labor intensive. Farmers face the greatest difficulties during the first few years when establishing a new living fence. Replanting, as seen in picture 3G, is often necessary to fill in gaps where the previous year's seedlings did not survive. Farmers must also be sure to begin pruning the trees when the seedlings are in the nursery, and there is always pruning work to be done to maintain the fence. However, once the living fence is established, farmers can develop their field inside the safety and security offered by the permanent protection, and they can utilize the many products from their living fence.

Desirable characteristics of trees used in living fences:

- Tolerate minor "injuries": living fences are susceptible to frequent injuries from pruning or animals and should tolerate them well.
- Fast growing: provide benefits to families as soon as possible.
- Compatible with crops: cannot have adverse effects on other tree species or crops they are associated with.
- Produce useful products like fodder, green manure, & fuelwood
- Protection- stiff branches, thorns, spines, nettles, or irritating latex to keep animals out.
- Vegetative propagation: ensures fast establishment while reducing the chance of spreading to pasture and cultivated areas.

Design: Thorny species (*Acacia sp.*, *Parkinsonia*, *Prosopis*, *Ziziphus*, etc.) tend to work best in living fences, though many people also use non-thorny species. Spacing among individual trees for most living fences varies between 25 and 75 cm, depending on the amount of rain and the rate of growth of the species used (Rocheleau et al., 1988). Cuttings of euphorbia bushes and other non-thorny species must be planted very close together (10-20 cm). Most living fences in Trees for the Future's projects tend to space seedlings 40-50 cm apart. Farmers who can afford barbed wire will often plant trees for living posts, and attach barbed wire once the trees reach the appropriate size (See *Gliricidia sepium*, lesson 8). If the trees are being planted inside a dead fence, plant the seedlings 1 meter away from the existing fence (even if it looks like you will be losing ground), or falling sticks and weeds near the old fence can crowd and kill the seedlings. It is best to stagger two rows of trees for any living fence instead of having only one line of trees (figure 3i). A variety of species should be planted & branches should be woven into the lower levels of the fence to create a strong barrier.

Pruning & Harvesting: The key for a good fence is to encourage early branching, because animals can only penetrate a living fence if there is not enough lower branching. If you wait too long and let the trees grow tall, it will be difficult to get them to grow lower branches. The seedlings must have their terminal buds pruned in the nursery stage and then again after they grow to 75 cm. Once mature, the trees can be pruned at the 1.5 to 2 meter height every year. Major pruning is best done during the dry season while trees are still in dormancy.



Pic 3G: Planting seedlings 40 cm apart to fill in a gap in the existing living fence.

Pic 3H: TREES' Field Rep Omar Ndao explains a living fence made of *A. nilotica* spaced at 50 cm.

Lesson 3: Agroforestry Technologies - Senegal Case Study

Insight into an agroforestry technology designed to maximize benefit for the participants

Confronting the Sahara desert, a mere 150 miles to the north and moving steadily southward, the farmers of Kaffrine in central Senegal face an environmental disaster. The Wolof people have unknowingly punished their soils with over a century of uninterrupted peanut farming. The annual harvest, which entails ripping peanuts out the ground, leaves farmlands exposed to the intense sun and harsh winds that last the long dry season. The need for fuelwood and construction materials has depleted local forests. The Wolof people are desperate for new ideas to deal with irregular rainfall, locust attacks, and the encroaching desert. Food security is only a dream. The baobab, tamarind, and bush mangoes that dot the horizon are all that remain of a once thriving forest.

The initial response of desperate farmers has often been to ask international development organizations to construct water pumps. In fact, access to fresh water often quickly creates a boom in vegetable and animal production. However, pumps alone have been an unsustainable solution. What at first appeared to be a springboard to sustainable development has proven to be the Trojan Horse of the African sahel.

It is a tragic, but common, scenario. Herds of animals concentrate at the water sources, trampling the soils and eating all that remains of local vegetation. New gardening industries further deplete the remaining forest resources as communities cut trees to build wooden fences that protect their precious gardens.

During our analysis, we learned that Senegalese farmers are tired of working - literally and figuratively - for peanuts. Production keeps falling, and the scant remaining topsoil is badly eroded by fierce winds in the dry season. Fertilizers are expensive, and farmers get only one payday per year, in November, after peanuts have been processed. The rest of the year is a painful waiting game. Animals have nothing to eat in the dry season after all grasses have been cut or burned, and women become exhausted from walking miles to collect wood for fuel.

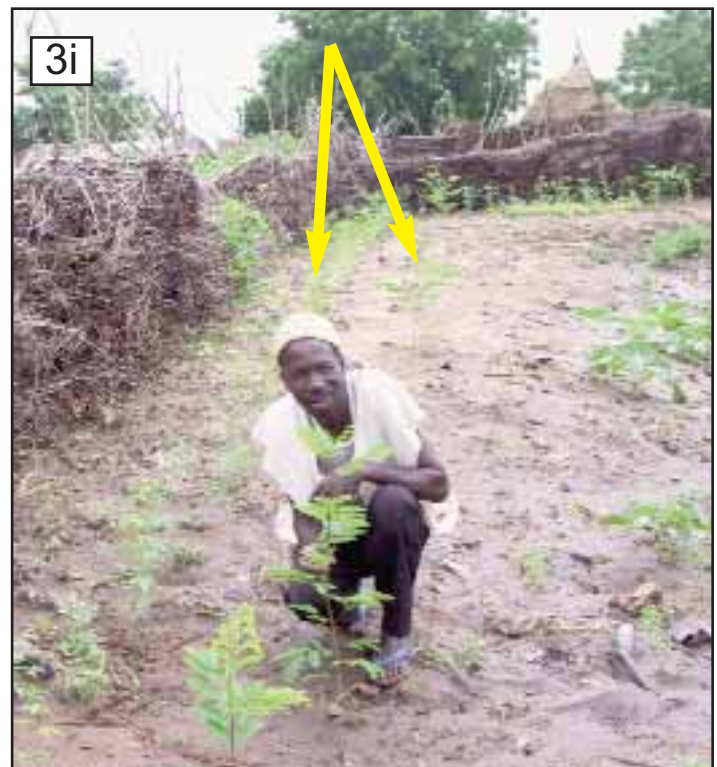
Our response was to work with local com-

munities to establish multipurpose windbreak/living fences. This agroforestry intervention directly addresses their major problems. We plant thorny trees on the outside to keep the animals out, and we plant fast-growing trees on the inside (pic 3J) to establish a tall windbreak.

From the mix of tree species in this agroforestry technology: 1) there is plenty of high-protein animal forage from the leucaena trees; 2) families are now producing 100% of their own fuelwood; 3) the *Cajanus cajan* and *Ziziphus mauritiana* produce pigeon peas and jujube fruits; 4) the *Acacia nilotica* trees produce several medicines; 5) the nitrogen fixing trees add plenty of nitrogen and organic matter (leaves) to the soil; 6) production has been diversified; and 7) inside these protected areas, we are now beginning to establish fruit tree orchards.

Families have changed the way they farm, collect firewood, improve their soil, feed their animals and protect crops.

Pic 3i: Getting started with 2 rows: Thorny acacia trees are planted on the outside for protection, while fast-growing leucaena trees are planted in the inside row. More species will be integrated in future years.



Do you understand how to combine windbreak and living fence technologies?

Lesson 3: Agroforestry Technologies - Alley Cropping

Enabling Objectives: By the end of this section, YOU will be able to 1) list the 2 major benefits of alley cropping, 2) list the characteristics of good alley cropping trees and shrubs, and 3) list 4 major considerations in the design & species used in alley cropping.

Overview: One of the most promising agroforestry technologies in the humid and sub humid tropics is alley cropping. Alley cropping is a system of growing food crops between parallel hedgerows of (usually leguminous) shrubs and trees. The hedges are pruned periodically during the growing season to provide biomass and to prevent shading of the growing crops.

Many farmers in developing countries do not have access to commercial fertilizer. Even if they did, they do not have the money to buy it. In some ways, that is fortunate, as chemical fertilizers can destroy soil structure. For them, there's good news: you can grow fertilizer on trees.

In equatorial regions, the rows of trees should be planted in the east-to-west direction, NOT north-to-south. By planting the rows east-to-west, the sun is able to shine inside all the rows of the field. If the rows are planted perpendicular to the path of the sun, then the crops will not receive enough sunlight.

The species of trees planted should be able to coppice (resprout and grow well after cuttings). Throughout the growing season, on a rotational system of 3-4 weeks, the branches, branchlets and leaves of these trees are cut and dropped around the crops growing between the tree rows (Pic 3P). They quickly degrade, adding large amounts of organic matter & nutrients to the soil.

On degraded soils, this brings important and sustainable increases in harvests (Agus et al., 1999). Other tests involving coffee crops showed similar increased yields and also marked improvement in the flavor and quality of the coffee (Lutz, 1998). Moreover, this is sustainable - it continues to increase harvests year after year. In many instances, once the growing season is ending and the dry season is about to begin, the trees are allowed to grow tall, since there is now no problem of shading out the crops (pic 3L). By the beginning of the next rainy season, the trees may be 3-4 meters tall and should be cut back. The wood can be used for fuelwood or construction, and the leaves should be plowed back into the land as "green manure". Figure 3J shows the

characteristics of good alley cropping trees.

Within each line, the trees are planted close together. In our experience we found it desirable to plant a double row, about 20 cm apart, with the trees about that same distance

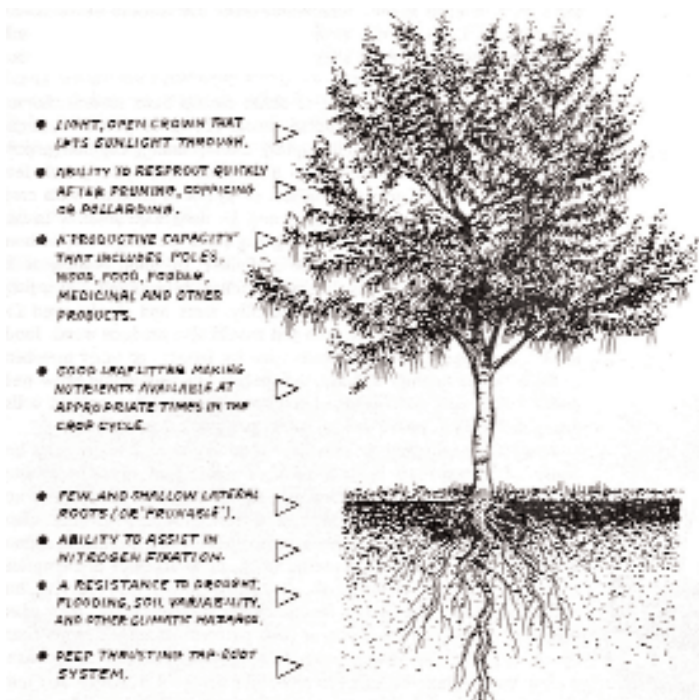


Figure 3J: Characteristics of good alley cropping trees
Agroforestry in Dryland Africa, ICRAF

apart in the rows. The two rows are staggered to keep the maximum distance (about 20 cm) between the trees. This greatly reduces "root binding" between the trees. You can have as many as 25 double-tree rows per hectare and a population of about 1,000 trees per 100-meter row, or as many as 25,000 trees per hectare (10,000 trees per acre).

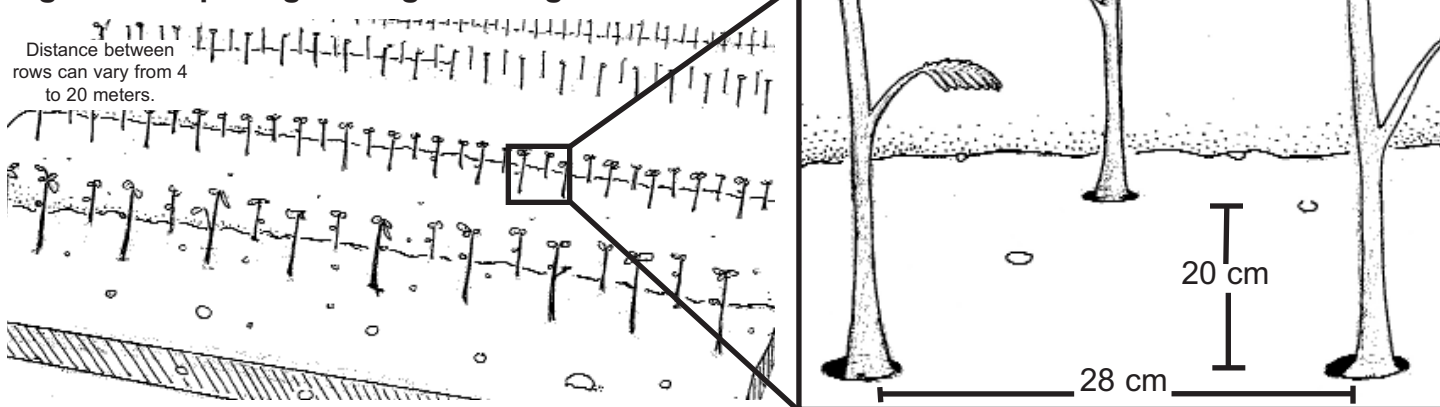
Alley cropping often requires a lot of convincing, as most hillside farmers believe they are already "land poor". Now you are asking them to plant rows of trees in their fields to grow bigger crops? You can imagine many are thinking "I know my family can eat corn; I doubt if they can eat trees". But once you can get a few demonstration plots started, you will find many people are convinced and ready to adopt the new idea.

Lesson 3: Agroforestry Technologies - Alley Cropping

Purpose: Alley cropping is the planting of strips of 'green manure' trees among field crops (pic 3L). These green manure trees serve the vital role of producing nitrogen-rich organic matter (mainly in the small, easily degradable leaves) which is harvested and mixed into the soil, ultimately increasing soil fertility. Despite the fact that the rows of trees reduce space for planting crops, experience shows that because of the increased soil fertility, production of corn in several different countries has increased by 150% (Szott and Kass, 1993). Alley cropping is also used to diversify the types of products that can be harvested from a field. For example, a field of corn intercropped with leucaena trees will produce massive quantities of corn, fuelwood, organic fertilizer and high-protein animal forage, all at different times of the year.

Design: Spacing among the rows of trees and among the trees themselves is highly variable. One of the major considerations is that the rows should run east to west - following the path of the sun to ensure that there is not too much shading among rows. Spacing between rows ranges from 4 to 20 meters, depending on the farmer's preferences. Spacing of 4-5 meters among rows (pic 3M) will create a labor-intensive system that will produce large quantities of wood and quickly revitalize worn soils with the massive amount of leaf fall (Nair,1993).

Figure 3K: Spacing Among Seedlings.



Harvesting: The rows of trees are often harvested at 50 cm to 1 meter height (pic 3N). Branches are used for construction and fuelwood, and leaves are mixed into the soil as an organic fertilizer, though leaves of some species like leucaena are also collected and used as a high-protein animal forage (after which the manure can be added back to the soil) (pic 3P).



Pic 3L: Let the trees grow tall during the dry season



Pics 3M & 3N:
Cut the rows
when you seed
your crops



Pic 3P: Mix the leaves into the soil

Can you meet the enabling objectives at the top of page 14?

Lesson 3: Agroforestry Technologies - Terraces & Contour Plantings

Enabling Objective: By the end of this lesson, YOU will be able to list the 5 major steps in establishing a contour planting.

Overview:

As more upland soils erode and degrade, and the demand for food crops increases, farmers are forced onto more marginal lands, including very steep hillsides. It is common to see a farmer planting his crops up and down a steep hillside throughout much of the world, even though it is obvious to everyone that the bare soils on those hillsides are eroding away, creating deep gullies.

Farmers who want to sustainably work these lands therefore construct terraces, often comprised of stones from the field. The eroding soil backs up behind them and, over time, these terraces become flat, looking like a series of giant steps down the hillside (pic 3Q).

The problem is maintaining these terraces in times of heavy rain. In the tropics, it can rain as much as 250 cm in a single night, and with the increasing numbers of hurricanes and cyclones, the potential for damage is enormous. Heavy rains can cause a large area of soil to break loose above or within stone walls, eventually stressing or crashing into the next terrace and continuing the chain reaction to the bottom of the hill.

And so the “living terrace” was developed. Here, a double row of trees, similar to some alley cropping arrangements, is planted on the contours of the hillside. As the land is worked, stones, weeds, and other debris are continually thrown behind the rows of trees, forming a wall that helps catch the eroding topsoil. Many of these terraces have tall grass, such as vetiver or napier, which are planted in combination with the trees. This further strengthens the terrace and can be continuously harvested as fodder for livestock, as organic matter to be added to the soils, and for other purposes.

In this way, there can be a stone terrace, backed by trees and tall grasses, strengthened by hundreds of thousands of tree roots. In areas of heavy rain, soil build-up behind these terraces is as much as 30 cm (1 foot) per year - rich topsoil that would otherwise have been washed away. The terrace is also providing a steady supply of organic fertilizer and humus from the leaves of the trees, as well as forage for animals, and a sustainable supply of firewood that can be used or sold. The greatest benefit is often the creation of a sustainable supply of water that is guided and captured into the ground during the rainy season and made available during the dry season.

Purpose:

Contour planting is an agroforestry technology that can minimize soil erosion on hillsides by up to 50%. Contour lines refer to a set of points on a hillside that are all at the same altitude. Contour plantings are vegetative strips that follow contour lines. They minimize hillside erosion by creating living terraces that encourage the infiltration of rainwater into the soil while slowing the speed of water washing down the hillside.

Five major steps in establishing a contour planting:

Step 1) Find and Mark the Contours: Find the contour using an A-frame (pic 3R and figure 3U), a water tube, or markers. Start creating contour lines at the top of the hill and move down to the bottom (see figure 3U). Start on one side of the field and, using the A-frame, find the contour as it meanders



Pic 3Q: Overstory trees with wheat in SW Uganda

Lesson 3: Agroforestry Technologies - Terraces & Contour Plantings

across the hillside, marking it with sticks or rocks. To provide maximum protection, the rows should be properly spaced. The vertical drop between contour rows should be about 1-2 meters. This does not mean 1-2 meters between rows, but rather the vertical drop (also known as the vertical interval) between rows should be 1-2 meters. Hillsides with a gentle slope will have long distances between rows (though it is best to limit this to 5 meters), while those on steeper mountain-sides will be closer together.

Step 2) Prepare the Lines: Using your markers as a guide, dig two channels along each contour line, leaving about 50 cm between channels. An animal drawn plow will greatly help. These channels will be used for seeding the trees. Note well: Some technicians suggest digging one major channel along the contour and seeding on the uphill mound created by the channel (pic 3S).

Step 3) Plant the Seeds/Seedlings: Pretreated seeds of multipurpose, fast-growing, nitrogen fixing trees can be sprinkled heavily along the channels. Cover the seeds lightly yet firmly with soil. Suggested species include *G. sepium*, *C. calothyrsus*, and *L. leucocephala*. You may also decide to plant seedlings or cuttings along the channels.

Step 4) Protect the Seedlings: The first year is critical for success. Extremely heavy rains, animals, and farmers themselves can ruin the work. If possible, the fields containing the newly planted contour rows should either not be cultivated in the first year or cultivation should be minimized. Be sure to weed the newly planted seedlings.

Step 5) Diversify: Beginning in the 2nd year, diversify the contour hedges with short-, medium- and long-term crops.

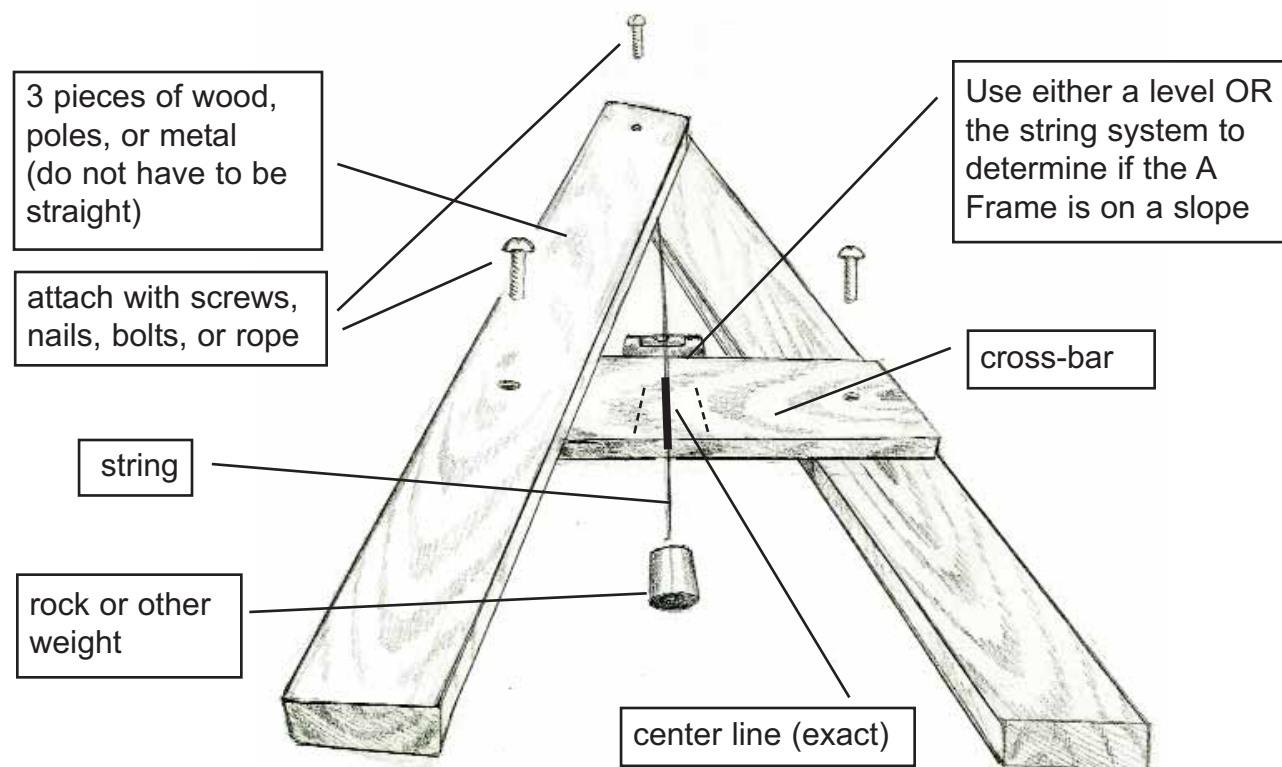
Pic 3T: On Flores Island in Indonesia, an area of 8,000 hectares (20,000 acres) was planted with leucaena contours. Flores' one river had always dried up several weeks before the rainy season began. Since two years after planting the contour strips, the river has never run dry again.



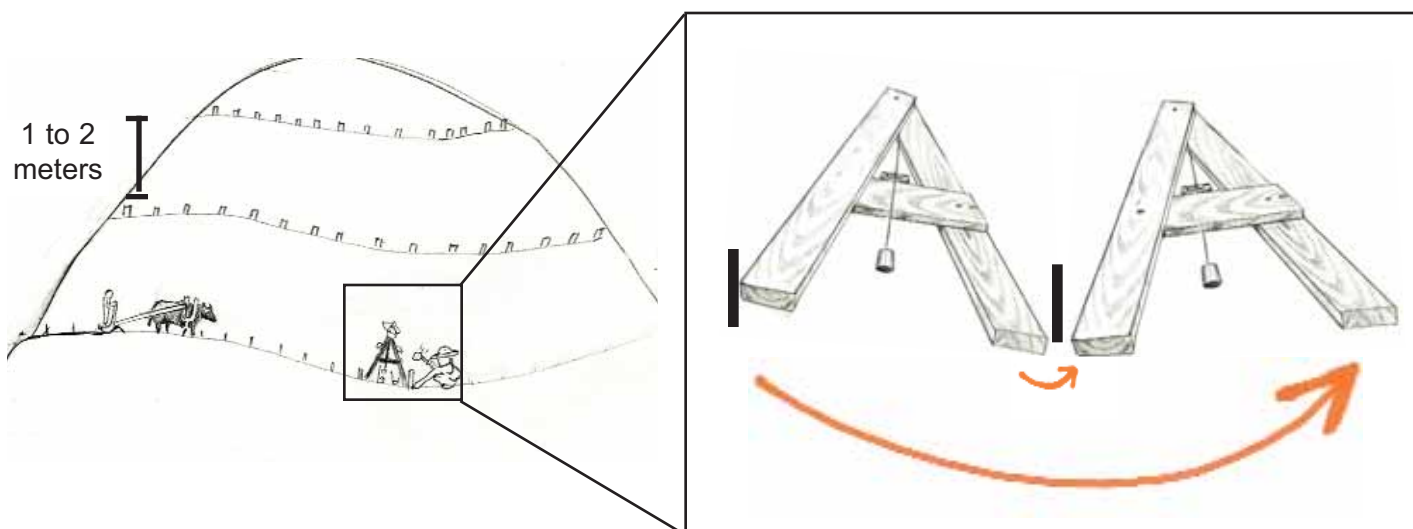
See the vetiver pamphlet included in this packet and the book on the CD for more info.

Lesson 3: Agroforestry Technologies - Terraces & Contour Plantings

Figure 3U: Constructing and Using an A Frame



To Determine the Center line: Stand the A Frame on a slight slope. Draw a line where the string meets the crossbar (/). Then reverse the legs and again mark the cross-bar where the string touches it (\). The centerline is exactly between those two points - mark it clearly.



To Mark a Horizontal Contour Across a Hillside: Start at the top of the hill. Mark one leg of the A frame with a stick. Slowly adjust the other leg until both legs stand on even ground and the string hangs across the center line. Then mark the second leg with a stick. Now pivot the A frame around keeping one of the legs firmly placed. Read just the positioning of the side of the A frame that was just swung around, and find the center line again. Mark this new contour point with a stick and continue across the hillside.

Lesson 3: Agroforestry Technologies - Firebreaks

Enabling Objective: By the end of studying this page, YOU will be able to describe two of the many approaches to creating a firebreak.

Fires are a difficult problem to address. It is best to start with education to stop people from starting fires. We are also working on combatting fires through agroforestry; these techniques are continually being developed.

Firebreak Case Study 1: Solid Green Walls To Stop Grass fires in the Philippines

The dry season in the mountainous regions of Southeast Asia is long and hot. This is especially true where the forests have been cleared - which is almost everywhere in the Philippines, where only 2% of the original forests remain. Nature protects these barren lands with a tough grass, *Imperata cylindrica*, that is found throughout the world. It is thick, tough and can grow on poor and degraded soils to a height of more than 10 feet.

When the uplands get hot and dry, it is almost explosive and all it takes is one spark. This happened during the "El Niño" in 1998. For weeks, smoke from the fires blackened the skies from Jakarta to Singapore, killing thousands. Every year the grass fires wipe out hundreds of upland villages and end many reforestation projects.

Orchards of mango and other fruit trees are especially susceptible to brush fires. Farmers have learned from their bad experience the importance of firebreaks in protecting their fruit. These **"living" firebreaks** are about 40 feet wide, and consist of 7 rows of trees that stay green and cool during the dry season. The shaded land beneath them maintains lush undergrowth making a solid, cool and green barrier about 20 feet high. When these breaks are planted in grids, they can stop almost any grass fire. They work because they quickly become solid green walls. One reason for this, and for their popularity in the community, is this undergrowth. Under the protection of these trees people can plant many other food crops: such as papaya, bananas, pineapple, and different root crops. The continuing leaf fall from the trees fertilizes and shades them while holding moisture on the land. This project, begun by TREES Technician Gabby Mondragon in the northwest Philippines, is teaching this technology to the people of the upland villages.

Firebreak Case Study 2: Stopping Fires with Cashew Trees on the Senegal-Gambia Border

Brush fires, frequently caused in the sahel by cigarettes, inexperienced apiculturalists, and animal herders camping in the bush, wreak havoc on dryland Africa, especially from March to June. The Dankou Forest, located on the border between Senegal and Gambia, is no exception.

The solution: Three lines of cashew trees, *Anacardium occidentale* (pic 3V), spaced ten meters apart, were planted in 2001. Why cashew trees? Cashew trees develop a thick, full crown, blocking most of the light from reaching the understory. This inhibits many grasses and shrubs from growing underneath them. Furthermore, the cashew tree has medium sized, thick leaves, which blanket the ground beneath the parent trees, further excluding growth of other vegetation. When a fire advances, the thick leaves on the tree and on the ground resist igniting, and with nowhere to pass underneath, the fire stops.



Pic 3V: Rows of large cashew trees like this one can inhibit the spread of brush fires.

picture courtesy of <http://commons.wikimedia.org>

Can you meet the enabling objective at the top of this page?

Lesson 3: Agroforestry Technologies - The Forest Garden

Enabling Objective: By the end of this Lesson, YOU will be able to list at least 4 major characteristics of the forest garden and at least 8 of the 10 zones.

A forest garden is a sustainable agroforestry system that fulfills economic, social, and cultural needs of the individual owners and provides biological conservation, carbon sequestration, and other valuable benefits to society (Kumar and Nair, 2004; Hairiah, 1997; Torquebiau, 1992). Agroforestry requires farmers to think both horizontally and vertically, and a forest garden is a perfect example of this. A forest garden goes by many names including permaculture, stacked polyculture, analog forestry and 'the perfect acre.' Ultimately, it is a production system that is harvesting products on over a dozen levels (Asfaw and Nigatu, 1995; Abebe, 2005). There is no specific design or methodology for a forest garden, just a set of desirable characteristics and zones.

Major Characteristics of a forest garden

- It allows people to sustainably meet their needs and produce a marketable surplus, by making maximum use of the land
- It incorporates the symbiotic relationships among plants animals and microbes
- It avoids the risk of economic dependence on one, or a very few, crops
- It provides a continuing supply of food and other crops
- It allows nature to provide organic fertilizers and pest controls
- Properly managed, it produces fruits and vegetables of far higher quality than those produced through monocultures

With their ecological similarities to natural forest ecosystems, forest gardens act as insurance against pests and disease outbreaks. They also act as a buffer against deforestation of natural forests by providing an alternative source for goods and services that people would otherwise collect from natural forests. The multi-tiered canopy structure is one of the most distinguishing features of forest gardens, especially in humid tropical lowlands (Kumar and Nair, 2004). About ten zones are distinguished in a typical forest garden.

Major Zones (See figure 3W)

Zone 1: The planting of "pioneer" or "fertilizer" trees that are initially planted to protect and support a forest garden. Because most of the species used for this purpose are fast growing, and also because they coppice--grow back after cutting--they appear at different heights throughout the site, constantly being cut back and re-growing. These trees are normally planted at spacings of about 3 meters, which provides an almost complete light canopy over the site, despite the periodic cutting of individual trees.

Zone 2: Ground crops that grow well in lower temperatures, higher humidity and partial shade.

Examples include pineapple, sweet and spice peppers, various kinds of beans and pulses,

Zone 3: Root crops that benefit from being planted close to the roots of the pioneer trees (cassava/manioc, sweet and yellow ginger, kamote (sweet potatoes) and other such crops).

Zone 4: Vine/climbing crops. The trunks of the pioneer trees offer an ideal way to construct trellises for overhead crops such as squash, gourds, "bitter melon", cantaloupe, chayote, and "air potatoes."

Zone 5: Various fruit and nut trees: shade-grown coffee, bananas, papaya, guavas, citrus, & cacao.

Zone 6: Hardwoods for long-term investment.

Zone 7: "Mini" livestock and poultry. The cool, shaded area is an ideal place to construct housing for various types of animals. For most classes of livestock and poultry there is an abundance of food.

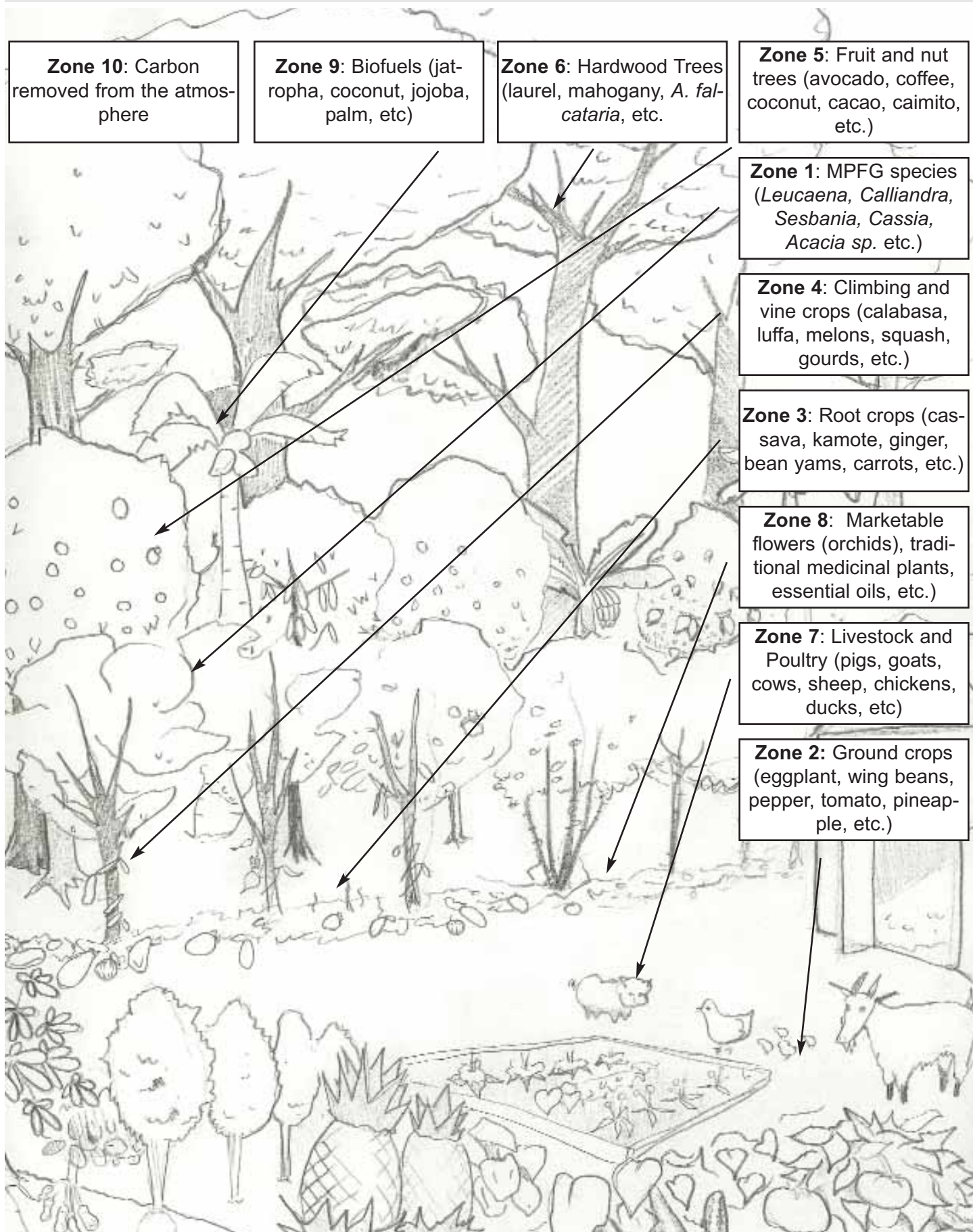
Zone 8: Marketable flowers (orchids), traditional medicinal plants, and other horticultural products.

Zone 9: The production of biofuels, whether in shade-grown jatropha, coconut trees, or any other oil-producing plants. Though this is a new technology, such fuels and feedstock are being produced on a limited scale in many villages already.

Zone 10: Carbon credit market for carbon stored in these forests.

Lesson 3: Agroforestry Technologies - The Forest Garden

Figure 3W: Zones of a Forest Garden

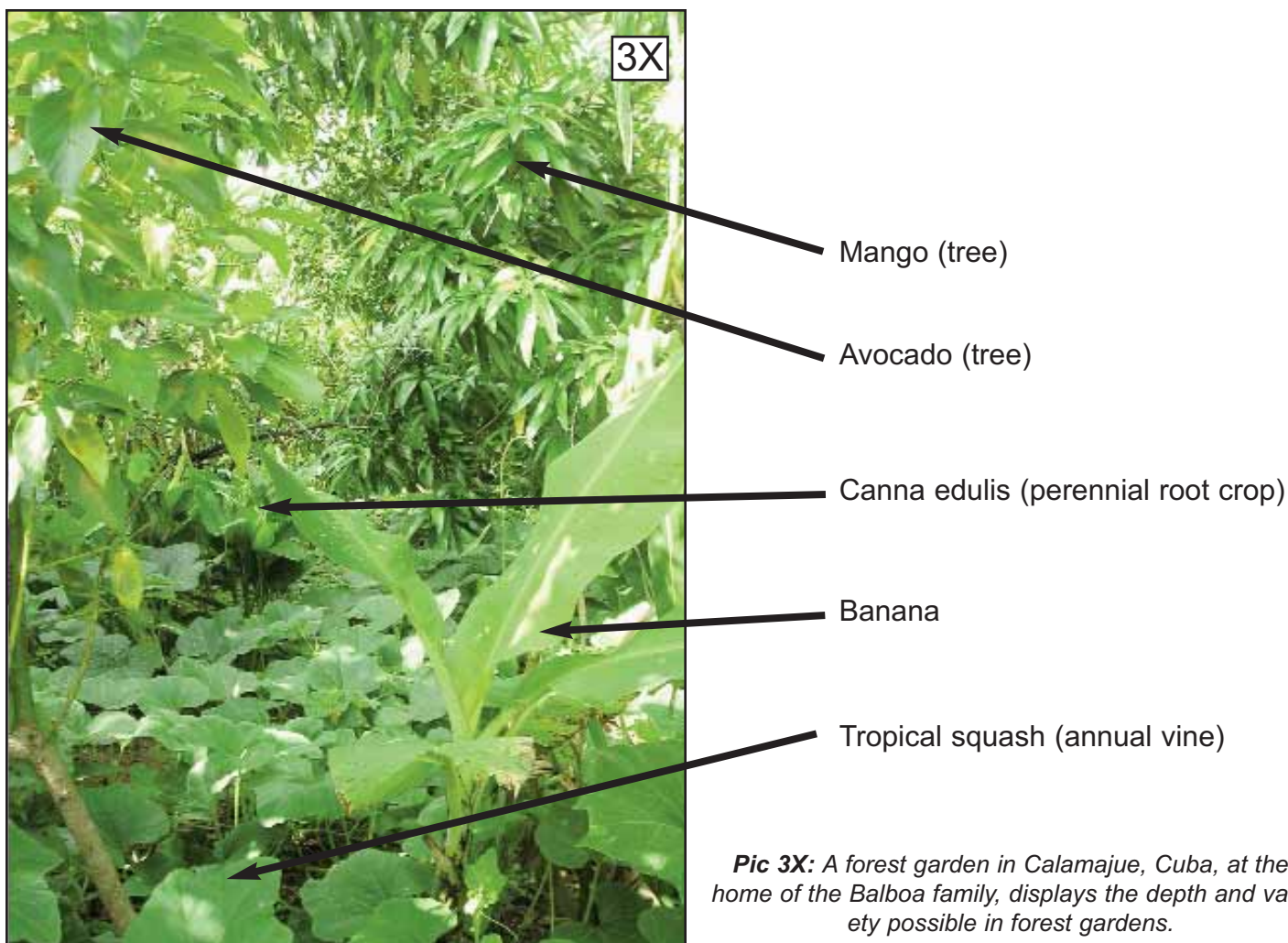


Lesson 3: Agroforestry Technologies - The Forest Garden

The Forest Garden and nutritional security, income generation and employment

A forest garden produces edible fruits, nuts, grain, rhizomes and tubers, leaves, and flowers, along with fodder, fuelwood, medicine, and construction materials. Forest gardens are also significant sources of minerals and nutrients contributing to food security of the owner (Wiersum, 1997). Perhaps most importantly, its contribution to food security is more pronounced during the lean season of the year (Tesfaye, 2005). As a result there is a growing interest in combining a forest garden with nutrition education as a practical strategy for improving household nutritional security for at-risk populations, particularly women and children in developing countries. In experimental studies, the target families significantly increased their year-round production and consumption of vitamin rich fruits and vegetables compared to the families without forest gardens. This, in turn, reduced deficiencies of iodine, vitamin A and iron (Kumar and Nair, 2004). Products from forest gardens usually are not contaminated by synthetic toxic chemicals and they can be more profitable than field crop agriculture due to lower production costs.

Experience with organic coffee (*Coffea spp.*) production in Central America showed that products from forest gardens could fetch premium prices. In West Java, as much as two-thirds of production is reported to be sold (Nair, 1993). In South African forest gardens, about 28% of such products were sold and the remaining was used for household consumption (High and Shackleton, 2000, cited in Abebe, 2005). In addition to generating cash income and subsistence products for the growers, forest gardens have a remarkable potential for rural employment generation. Studies show that forest gardens required on average 32.6 hours of labor per family per week, with women contributing roughly half (Abebe, 2005).



Pic 3X: A forest garden in Calamajue, Cuba, at the home of the Balboa family, displays the depth and variety possible in forest gardens.

Lesson 3: Agroforestry Technologies - Integrated Production Systems

Enabling Objective: By the end of reading this case study on coffee, YOU will be able to explain at least one example of why we must better integrate food production systems.

Next to oil, coffee is the most traded commodity in the world (Gole et al., 2002). Cacao, which is used to make chocolate, is also a valuable commodity in world trade. Both are produced by trees that naturally grow in tropical forests, and both have been produced and harvested in their natural setting for centuries.

In the late 1960's it became clear that the tropical forests of the world were being rapidly destroyed threatening the supply of these two important commodities. The World Bank and other organizations sought ideas for the continued production of these crops without dependence on the surrounding trees.



Pic 3Y: *Fields of coffee that has been bred to grow in full sunlight. The lack of an overstory and the use of chemicals minimize biodiversity in these fields and expose soils to serious erosion.*

Hybrids of both plants were developed (pic 3Y). The new variety of coffee, as well as cacao to a limited extent, can be grown as plantation crops in full sunlight. The plants were significantly changed, and were now using their top foliage to provide the shade that was provided by the forest. These modified plants are shorter, mature faster, and produce higher yields in their earlier years.

The management system promoted for these new varieties of coffee entails clearing away undergrowth and other plants, especially trees. Herbicides keep the undergrowth away and pesticides reduce damage from insects. Chemical, rather than organic, fertilizer maintains productivity.

These systems are much more difficult for these trees to endure. In a forested state, coffee trees can produce for over 100 years. Grown in plantations, their life expectancy is reduced to only 25-30 years. Initial yields under the new system were much higher, but under these conditions the nutrient levels of the soils quickly dropped, as did their organic matter and capacity to hold water.

Chemical fertilizers restored the levels of "macro"-nutrients - nitrogen, phosphorous and potassium, but not the "micro"-nutrients such as iron, zinc and copper. The result was that as the richness of the soil decreased, so did the yields - and the flavor. At the same time this was happening (and probably because it was happening) markets in Europe and North America began demanding organically and sustainably produced foods, including "shade-grown" coffee.

Markets began providing ground coffee with various flavors added and powdered cream, also in various flavors, hoping to cover up the fact that the coffee itself had very little taste. At the same time, coffee roasters who advertised their product as "shade-grown" found they could command the best prices.

This situation continues and offers upland farmers a great opportunity not only to get higher prices for their coffee but also to save and improve the productivity and water retention capability of their lands, while also allowing them to produce more products. For example, in upland areas, much of the land unsuitable for tilling is used as pasture. The tree leaves that provide shade for their coffee also offer a high protein forage supplement for their cattle. Trees, coffee, and cattle can work in a system that increases overall production while improving the water retention ability and soil quality of mountainsides.

What does this case study say about integrated production systems?

Lesson 4: Agroforestry for Livestock Management

Lesson Objective: By the end of Lesson 4, YOU will be able to: 1) define silvopasture 2) cite 3 problems with grazing systems; 3) list 5 benefits of zero-grazing systems; 4) identify 3 forages appropriate for your region; 5) list major silvopastoral management tools, and 6) list at least 3 socioeconomic benefits of silvopasture.

Overview

In many developing countries, livestock production is a major contributor to gross domestic product (GDP). For example, livestock production contributes 30-40% of the GDP in the Sudano-Sahelian countries of West Africa (Nair, 1993). Agroforestry practices mainly concerned with the management of trees, forage and livestock is known as silvopasture. The term silvopasture translates into 'forest-pasture', as the prefix 'silvo' was derived from a Latin word that means 'forest'. In silvopasture systems, forage crops are deliberately introduced into a timber production system, or trees are deliberately introduced into a forage production system. The interactions among timber, forage, and livestock are thus managed intensively to simultaneously produce timber, a high quality forage resource and efficient livestock production. Overall, silvopasture can provide economic returns while creating a sustainable system with many environmental benefits (Pagiola, et al., 2004). These systems range from traditional silvopastoralism to very high intensity cut and carry fodder systems. Below a brief account of traditional grazing systems and cut and carry systems are discussed.



Pic 4A: Cattle grazing in Ethiopia on hilly land that is heavily overgrazed, with few trees and rampant erosion

Traditional Grazing Systems

Peace Corps volunteers throughout Central America's degraded uplands have seen the damaging effect that livestock can have on the land (pic 4A). However, livestock are an essential component of farming throughout the Developing World, as they provide labor, fertilizer, transport, and food. Animals are also a major investment for families and have many social implications. Therefore we should take a closer look at how animals can fit into programs that save and restore degraded lands.

One of the most important points you must first understand is that: animals are not causing the



Pic 4B: Corral used for confinement rearing built from locally available materials

problems, management systems are. Most communities throughout the developing world allow their animals to roam the countryside, often herded by young men or boys. These herds of animals have a significant impact on the environment. They eat everything, including tree seedlings, and their hooves compact the soil, keeping forests from regenerating while causing long term damage to the soil. To make things worse, herding animals in the hot sun is an inefficient way to raise animals. They are stressed by the high temperatures and lack of water, just as people are, and the grasses and seedlings they graze on tend to be low in nutrients. **It is now time to consider a new management system.**

Lesson 4: Agroforestry for Livestock Management

Planning Considerations

Before establishing silvopastoral systems in an area, one must assess the value of integrating forestry and agriculture for economic success and environmental sustainability compared to local land used. Environmental requirements (e.g., planting trees, stream-side protection, and wildlife habitat maintenance) also may vary between locations. Select and use trees and planting/harvesting patterns that are suitable for the site, compatible with planned silvopastoral practices and provide desired economic and environmental returns.

Design and Establishment

Silvopastures can be established on any land capable of simultaneously supporting tree and forage growth. The pattern of the distribution of trees on the land is an important factor for silvopasture success. Trees can be evenly distributed over the area to optimize growing space and light for both trees and forage. Alternatively, grouping trees into rows or clusters concentrates their shade and root effects while providing open spaces for pasture production. Trees are typically pruned to increase light penetration and develop high-quality timber.

Management

The management of silvopasture requires a good understanding of forage growth characteristics as well as the timing and duration of grazing to avoid browsing of young tree seedlings. Livestock should be excluded from tree planting areas during the first year of plantation establishment. Improper management of silvopasture can reduce desirable plants due to overgrazing and soil compaction.

The major silvopasture management tools include:

- tree harvesting, thinning and pruning
- fertilization to improve both forage and tree production
- planting legumes for nitrogen fixation and forage production
- multi-pasture, rotational grazing
- rotational burning
- supplemental feeding
- developing water sources (e.g., stock tanks, windmills, ridge reservoirs, etc.)
- Using fencing, tubing, plastic mesh, repellents, & seasonal livestock exclusion to reduce damage to young seedlings



Pic 4C: Confined livestock fed selected nutritious fodder



Pic 4D: Preparing leucaena fodder for livestock



Pic 4E: Leucaena used for forage & fuelwood production

Lesson 4: Agroforestry for Livestock Management

One effective and highly profitable livestock management technique is to confine the animals, which is known as *confinement rearing*. In this system, the food is brought to the animals, the animals do not go to the food. This is also known as a *cut-and-carry* or *zero-grazing* system. In these systems, one acre of forage can maintain up to 20 cow-calf units.

Confinement / Cut-and-Carry Systems

In a cut-and-carry system, animals are penned in a specific area (pic 4B). Families use walls, thorny branches, poles, or living fences to keep the cows, sheep, or goats enclosed. This protects them from other people, pests, and diseases, and it keeps them from wandering.

Because animals are not allowed to graze in open lands, forage must be brought to them. This gives the owner an opportunity to select the very best food for the animals (pic 4C).

Selecting Forage & Forage Trees

There is a wide range of great animal forages that communities utilize around the world. Just like people, animals need a well-balanced diet. The ultimate goal of rearing animals is to provide them with living conditions that will help them stay healthy and reproduce quickly. Grass alone is not enough. Animals need protein, macro and micronutrients, minerals, and plenty of clean water.

The question is: what species of trees are useful for forage production? Almost every country in the tropical world has some species where the leaves are used as forage. Trees for the Future's experience has largely been with the species *Leucaena leucocephala* (pic 4D) because it grows well under a wide range of conditions, quickly coppices (grows back) when cut (pic 4E), and produces a large quantity of leaves, even through the long dry season. The leaves are especially palatable and contain about 27.5% crude protein, plus high levels of Vitamins A & D (National Research Council, 1984). Communities have also had success using grasses and bushes including dwarf napier/elephant grass, tephrosia vetch (pic 4F), and tree lucerne (pic 4G).

Over the past 32 years, Trees for the Future has helped livestock growers plant millions of trees. In the Philippines, Trees for the Future assisted 90 families to plant 66,000 trees, using the leaves to fatten cattle. A few years later, working with the Cattlemen's Association of Madura, Indonesia, technicians helped them plant over 22 million trees. This increased the available forage supply by 15% - much of it in the dry season when the forage supply had always been dangerously low.

Nutritionists have pointed out that leucaena is in the Mimosa family and the leaves contain an irregular (alkaline) amino acid called "mimosine", which can reduce calving rates under certain circum-



Lesson 4: Agroforestry for Livestock Management

stances. These leaves should be fed to single-stomach animals in limited amounts (25% for goats and sheep; none to horses or mules) but can be fed to large ruminants up to 30% of the total ration.

While Trees for the Future has assisted many forage projects to achieve good results, there is a great need for more research to determine even better methods to increase both the quantity and quality of animal protein for people and to bring income-generating trees back to the world's degraded lands.

able to gain 150 kg. However, in the dry season, they lose about 25 kg so they actually only achieve about 33% of their genetic potential.

Putting in a confinement system costs far less than installing and maintaining perimeter and division fences, especially on rough land where many livestock programs are located. Some raisers ask what can be done with all that rough land. One suggestion is to plant trees, including fruit and timber trees in combination with forage trees, to provide high quality forage for the herd, especially in the dry season.

The Economics of Cut-and-Carry Systems

From an economic perspective, this is the obvious best choice. In upland areas, it usually takes anywhere from three to seven acres of land, depending on the type of forage, to maintain one cow-calf unit. With the confinement or cut-and-carry system, one acre of forage can maintain up to 20 cow-calf units.

Grazing systems are especially difficult to maintain in tropical areas where there are distinct rainy and dry seasons. Working with Banteng (an Asian relative to cattle), researchers learned that yearling bulls gain about 75 kg of body weight in the rainy season so, for the year, they should be

Pic 4H: This goat is not foraging in degraded pastures, and is enjoying a healthy, nutritious meal



Pic 4J: This is not an uncommon sight on tropical pastures near the end of the dry season.

Short of forage, this cow walked throughout the dry season looking for food in the hot sun. It will take an entire rainy season to restore this cow's health. The result is fewer calves, stunted growth, low productivity, and serious health problems for the herd.

Pic 4K: High quality beef can be produced with the cut-and-carry system. This bull gained 900 grams (.9 kg, 1.95 lbs) every day for 240 days! The ration was sugar cane tops and leucaena tree leaves. No grain was used.



Can you meet the lesson objectives at the top of page 24?

Lesson 4: Agroforestry for Livestock Management

Experience with these systems, much of it in Southeast Asia where the price of land makes it prohibitive to graze livestock, has shown that confinement rearing greatly improves production by generating more milk, faster gains, and a higher calving percentage because the animals are in the cool shade with clean water and better forage. There are no hills to climb, no insects, no snakes, no predators, and no hot sun. There is also far less sickness and mortality. The reason is simple: the animals are where you can keep an eye on them.

Because the animals are confined, daily management is far easier. Sickness and other problems can be quickly identified and remedied before it is too late. Because the cattle are comfortably housed with forage, clean water and minerals at all times, they waste far less energy compared to animals that spend their lives walking around in the hot sun, always thirsty, and always plagued by insects and heat. Therefore more energy goes into the production of more calves, more milk to make them grow, and more meat to sell each year. Because the manure is easily captured, it serves as an excellent source of organic fertilizer that can be transported to crop fields, gardens, or nurseries.

Once again, this system depends heavily on the use of forage trees, which are the deep-rooted leguminous trees needed to restore the land. Thus, a high percentage of the ration, about 25% for most cattle, is available from the reforestation program. These tree leaves (especially *Leucaena leucocephala*) have the ability to greatly increase growth rates and milk production, because they have high levels of protein. An average herd of dual-purpose cattle needs a ration of about 11-12% protein. Local grasses have about 6% in the rainy season and 4% in the dry season. Leaves of the *Leucaena* tree have about 27.5% protein, high levels of Vitamins A and D, and are palatable to the animals (National Research Council, 1984).

Our program has proven many times that improving the feed ration and decreasing the stress and energy requirements can double annual growth and milk production in an average herd (pic 4J and 4K).

Looking at this system from a national perspective, it is possible to rapidly increase livestock numbers through higher birth rates, without major investment. The average yield of meat or milk per animal can be increased by as much as 40% because energy requirements are lowered and more of the forage goes into production. It also provides meaningful jobs in rural communities where they are needed most.

Social, Economic and Environmental Benefits of Silvopasture

Integrating trees, forage and livestock into a land use system raises the production of marketable products while maintaining long-term productivity. The system produces multiple products and hence reduces economic risk. Because the management cost for the timber and livestock component is spread out, the system provides relatively constant income from livestock/product sale and sale of trees, fruit and timber products.

Grazing can enhance tree growth by controlling grass competition for moisture, nutrients and sunlight. Well managed grazing provides economical control of weeds and brush without herbicides, maintains fire breaks, and reduces habitat for persistent rodents. In addition, livestock manure recycles nutrients to trees and forage.

Trees that provide shade or wind protection can have a climate-stabilizing effect, reducing heat stress and wind chill of livestock. Trees can cut the direct cold effect by 50% and reduce wind velocity by as much as 70%. Planting trees on grazing lands is a protective measure that can improve livestock performance, reduce their mortality, and decrease their feed requirements. Moreover, silvopasture has the potential to improve water quality and wildlife diversity. The trees protect the soil from water and wind erosion, while supplying organic matter to improve soil properties (Rocheleau et al., 1988; Nair, 1993). Unlike concentrated livestock management, silvopastoral systems are more environmentally friendly and less likely to raise environmental concerns related to water quality, odors, dust, noise, disease problems and animal treatment.

Lesson 5: Conservation Techniques - Fuel-efficient stoves

Lesson Objective: By the end of this page, YOU will be able to: 1) explain the basic principle of fuel efficient stoves; and 2) list the 4 main ingredients and 8 major steps in making a mudstove.

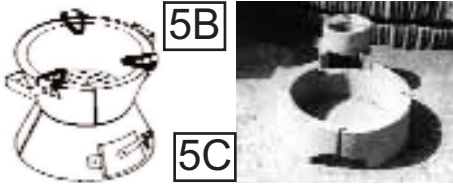
Fuel Efficient Stoves

The demand for fuelwood has placed a great pressure on tropical forests and resulted in rapidly depleting forest cover, soil erosion and desertification, especially in developing countries. Fuel-efficient stoves can decrease wood consumption by as much as 30-40%, and not only reduce the amount of wood used for cooking but also reduce the amount of toxic smoke produced. Models like the lorena stove (pic 5A) channel the smoke out of the kitchen, decreasing the prevalence of respiratory problems among women and children. This makes a major difference in people's lives by protecting their health, and saving money and time which would otherwise have been spent searching for wood.

There are several types of fuel efficient stoves; many are variations of conventional designs. They are made from clay, mud, metal and other simple materials. The basic principle of all fuel-efficient stoves is that they are better insulated than traditional models. This improved insulation is achieved by surrounding the fire with walls. Whereas traditional cooking methods often entail the use of just three rocks, new stove models ensure that the heat is forced up toward the bottom of the pot and does not escape out the sides of the stove.



5A



5B

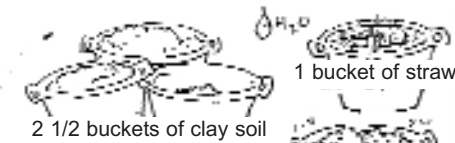
5C



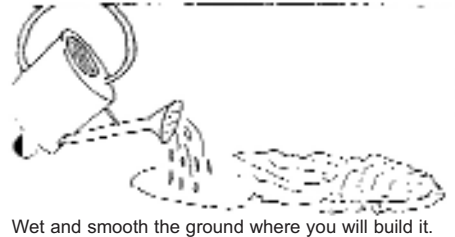
5D

5A: Lorena Stove
5B: Forno Jumbar Stove
5C: Ethiopian "Mirte" Stove
5D: Fixed Mud Stove

How to Make a Fuel-Efficient Mudstove with No Money



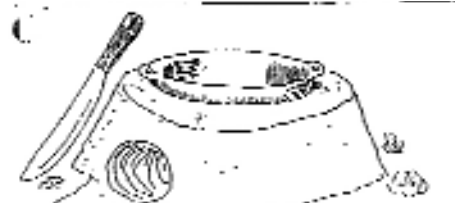
Mix the dry ingredients
Then add water
Stomp the mud pile, cover it,
and leave it to soak overnight



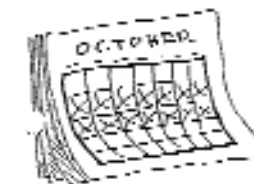
Wet and smooth the ground where you will build it.



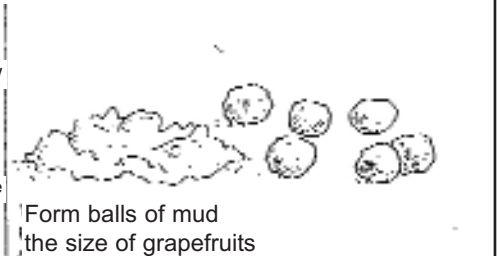
Pack mud balls around the rocks and the pot. Be sure to pack mud into all the gaps.



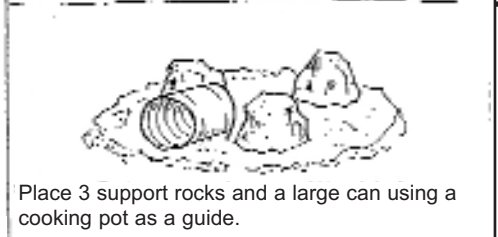
Cut around the pot and shape the stove with a machete



Let the mud stove dry for 2 weeks before using it - make sure it does not get wet.



Form balls of mud the size of grapefruits



Place 3 support rocks and a large can using a cooking pot as a guide.



The mud stove mound. Build a shelf for the wood.



Waterproof the stove with a mixture of ground baobab leaves and water. You may need to find an alternative sealant.

Mud stoves are fuel-efficient because they channel all the heat and smoke around the pot. The pot and fire are insulated by the mud mixture. You are saving time and trees.

Lesson 5: Conservation Techniques - Integrated Pest Management (IPM)

Lesson Objective: By the end of studying this page, YOU will be able to 1) define Integrated Pest Management; and 2) identify at least 2 IPM techniques that you and your communities can use.

Integrated Pest Management (IPM)



In agricultural systems where chemical pesticides are NOT used, farmers can use a wide variety of natural measures to protect crops, vegetables, and seedlings. By understanding the pest's natural biological characteristics - for example how they travel, what they eat, and what they are attracted to - farmers and researchers have developed a variety of techniques that trap, kill, and repel insects. Integrated pest management

can be defined as the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable.

We must clarify that one way to combat pests and diseases is by keeping your vegetation healthy. When vegetables lack nutrients and water, they become more susceptible to infestation. Natural enemies such as bats, birds, wasps and ladybugs should also be encouraged.

While many books are available that explain dozens of IPM techniques, here we will explain just one 'cocktail' that is effective against most insects. Its ingredients can be found throughout the tropical and sub-tropical world. We recommend using as many of these plant materials as you can find - others can be mixed in as well, such as mint, tobacco (depending on the crop), and tomato leaves. We also recommend that you include soap. Soap helps IPM concoctions not only adhere to the surface of plants, but it is also a slippery weapon effective against small sucking insects, such as aphids and thrips, and larger bugs and insects when concentrations surpass 8 grams per liter.



Pic 5E: IPM Cocktail

IPM Cocktail (Pic 5E) Ingredients:



½ kilo marigold flow-
ers



100 grams diced hot
chili peppers



2 kilograms of neem
seeds (leaves also
effective)



1 kilogram of
mango leaves



1 kilo leaves of
Ricinus communis

Ingredients Not Pictured:

- 6) 10 Liters of water
- 7) 1 kilo leaves of *Catalpa longissima*, Haitian oak, (if available)
- 8) 8g/L Plain, fragrance free, locally-made soap (such as peanut soap)

Directions:

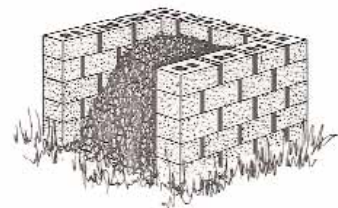
- 1) Crush all ingredients together (neem kernels must be cracked). Dissolve soap in the solution by either heating it in a separate container or by scrubbing firmly (cut it into small pieces if necessary).
- 2) Mix and let soak overnight in water - **do not store in the sun.**
- 3) Strain the concoction with an old t-shirt or cloth.
- 4) Apply solution in the evening by either dipping infested branches in the solution, brushing the solution on the infected plants with a branch, or spraying.

Lesson 5: Conservation Techniques - Composting

Lesson Objectives: By the end of this section, YOU will be able to 1) list the ingredients your family/community can put in your compost; 2) explain how a compost creates humus; and 3) explain 5 aspects of managing a compost.

Overview

Compost is a cheap and effective organic mulch that can be used instead of commercial fertilizers to improve the soil. Composting is a process that transforms organic materials into humus. As we learned in Lesson 1, soil is composed of both organic and inorganic material. Humus is the organic matter component of soil that is being destroyed and eroded throughout much of the world. Many types of organic waste can be decomposed to create a valuable natural fertilizer that enhances the quality of your soil.



Proper use of compost improves soil structure, texture and aeration, and increases the soil's water-holding capacity. It loosens clay soils and helps sandy soils retain water. Adding compost improves soil fertility and stimulates healthy root development in plants. The organic matter provided in compost is further broken down by microorganisms in the soil, keeping the soil in a healthy, balanced condition. Adding compost to gardens, nurseries, and crop fields adds natural strength to soil in the form of nutrient-rich organic matter along with plenty of beneficial microorganisms. Adding chemical fertilizers is a short-term fix that actually causes long term problems, while adding compost to soil is a long term solution that causes no problems.

What Goes into Compost?

Proper composting relies on aerobic decomposition, which consists of: 1) carbon and nitrogen-rich organic materials, 2) air, and 3) water. Carbon-rich materials are old brown or yellow fibrous vegetation like stalks and dry leaves. Nitrogen-rich material includes green vegetation and fresh manure.

You can put nearly any organic waste into a compost; just be sure it does not have any pesticides or other chemicals on it. Anything green or brown can be added. Crop residues, weeds, peanut shells, grass clippings, weeds (the high temperatures and decomposition will kill the weed seeds so they are not distributed when you use your compost), tree leaves, animal manure, fruit peels, egg shells, coffee grounds, etc. You should also mix in soil and a little wood ash.

Putting it Together

The compost will begin decomposing more quickly if the materials you add are chopped into small pieces. Mix the compost pile regularly to maintain adequate aeration; the decomposition process will need plenty of oxygen or it will begin to smell badly. During rainy seasons, the compost can be arranged in a pile. During dry seasons, it is best to put it in a hole or pit to keep the moisture from evaporating.

The Internal Processes

In the presence of air and water, various kinds of fungi and bacteria feed on organic material and convert them into humus. As this takes place, heat builds up in the pile/pit. Properly made compost will reach 65-70 degrees Celsius in 2-4 days due to the processes caused by bacteria; then it will cool down. This heat will kill pathogens in the soil and weed seeds. Mix it after a couple of weeks and it will heat up in the interior again. Continue this process. You will know the compost is ready when it no longer heats up after being aerated. Finished compost is dark brown and earthy-smelling.

Things to Avoid

Do not let it get too wet.	Do not add meat or bones
Be sure it is mixed and gets enough oxygen.	Keep the compost out of full sunlight.

Lesson 6: What are the Perceived Needs of the Community

Thoughts from Trees for the Future's Founder, Dave Deppner.

The people who will actually be implementing your project - the people living on these degraded lands - are, for the most part, extremely poor. There is no way they can voluntarily participate unless they are convinced, first, that the project is intended for their benefit, second, that the benefits will address their needs, and third, that these benefits will come quickly - poor people can't wait very long.

If an agroforestry or reforestation project is to succeed, it is absolutely essential that it begin by meeting the people of the community and getting them to tell you what their problems are, at the same time asking them what ideas they have to resolve those problems. If the project is to have any chance of success, involvement of the entire community is the key! Answers obtained from some government report will generally not convince local families to participate in your project.

Local needs will generally not coincide with national or global priorities. A family that is watching their hillside farm wash away probably knows, or cares, little about loss of diversity or global climate change. And yet, one of the great things about restoring tree cover is that, with good project design, it not only brings great benefit to the

local community but also contributes to solving these global and national concerns.

Ancient Chinese claimed that trees bring as many as 5,000 benefits. Many of these can be covered by a single word: SUSTAINABILITY!

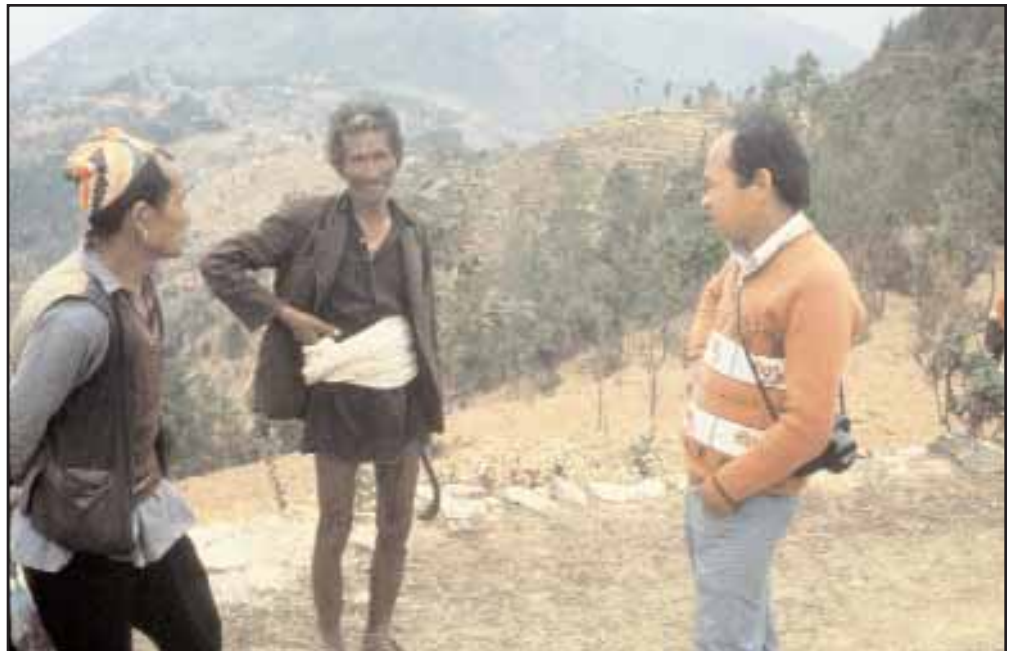
Does your project allow local people to remain on their lands, not just for a few years but sustainably? Does it increase their food production sustainably? Does it provide them with a sustainable source of low-cost fuel? Does it improve the quality of their lives sustainably? If, for example, your project has convinced hundreds of families to donate many hours of hard labor and a portion of their precious land, and then, only a few years later, the trees are gone, it might have been better if you had never started the project. Poor people don't have the resources to do the job twice if it was poorly planned the first time.



Dave Deppner



Nand Strestha, now the Deputy Minister of Agriculture in Nepal, speaks with farmers in the town of Musikot about planting forage trees to protect the fragile slopes and to keep their work animals healthy.



Lesson 7: Income-Generating Activities

Special Assignment: Interview at least five different community leaders to identify 4 or more non-timber forest products in your area.

For this assignment, interview 5 or more other community leaders to identify non-timber products that you can potentially produce and sell from local agroforestry projects.

One of the most critical aspects of an agroforestry project is whether it brings immediate benefit to participating communities. This is why it is important to plant fast-growing trees. Most communities where we work do not have 30 years to wait before they receive benefits from the trees.

Here are just a couple of the hundreds of possible products:

Honey production



Vegetable production



Selling leucaena leaves as high-protein animal forage



Cacao and coffee



Handicrafts and jewelry



Lesson 7: Income-Generating Activities - Extra Examples

*These examples are for interested individuals only.
They are not included in the agroforestry exam.*

How to Make Body Lotion for Sale

- Popular Among Women During the Dry Season

Materials for one batch

- 1 liter of cooking oil (vegetable or peanut)
- 1 large bar of scented soap
- 1 liter of water
- Perfume (the quantity you add depends on how you like it)
- Anything else you want to add (ex. neem leaves, lime/lemon juice, etc.)
- 1 bucket (remember this bucket may smell afterwards)
- 1 grater - If you don't have a grater, get a Nescafé lid or large can
- 1 nail
- 1 Coca-cola bottle, rock, or hammer
- 1 whisk or something to mix with
- Containers in which to put the lotion (bags, bottles, etc.)

Method:

1. Begin by pounding holes into the Nescafé lid or tomato can with the nail and the Coke bottle or rock. The rough side will be used as a grater.
2. Start grating soap into your bucket. If the grated soap is damp, leave in the sun for a few hours or a day. Dry soap is easier to grate.
3. Add the water. Use the whisk to mix well.
4. Add the oil very slowly. Continue mixing.
5. When it is well mixed, add perfume as you prefer. You can also add neem extract to give your lotion anti-bacterial and anti-mosquito properties.
6. Once you have reached the desired consistency, smell and feel, simply put your lotion into the containers that you have set aside.
7. They are ready for sale

Soap Elongation

Why do it?

Not only can you turn one bar of soap into four, but you can also turn this soap into anti-bacterial soap by using the neem leaves.

Materials:

- ½ kg peanut soap
- 1 liter water
- salt
- bucket of neem leaves (crushed)
- neem seed kernels are preferred
- large cooking pot with cover
- spoon
- 5 or 6 plastic water bottles (cut the tops off)
- a tomato pot with holes (grater)

Method:

1. Grate the soap using the tomato can grater.
2. Boil the neem leaves in a liter of water. Include the neem branches and cracked kernels to make it stronger. Boil it until the water turns green, then discard the leaves.
3. Add the soap and a little salt to the neem water. Mix well.
4. Pour the mixture into the containers (water bottles) to dry.
5. Leave to dry for 3 days.
6. Peel off the plastic bottle and your soap is ready for use or sale.

Lesson 8: Agroforestry Tree Species - Introduction

Lesson Objective: After reading this page and reviewing the tree species descriptions on pages 36-47, and using the information in this training packet and from any outside sources you may have, write a one paragraph description for 2 tree species appropriate to your region that will be extremely helpful in improving local agroforestry systems and why.

In agroforestry, trees are planted as an initial step in a long, continuing program of sustainable land management. Anyone who recommends tree planting as an end in and of itself is not doing the participants any favors, and those efforts will not last very long. Establishing a sustainable agroforestry system will occur over a number of years. The first year or two are the most important: participating communities must have some level of success and must see some harvestable product or significant benefit. After the initial pioneer species are established, diversifying the system will become much easier.

In the first year, you will start with a low number of species, perhaps just one to three. Non-native species that have been researched and used in agroforestry projects for decades are often used in these initial steps, and they are the stepping stone to creating conditions that will allow for the return of lost biodiversity. Regardless of which species, the trees you will identify and plant over the next year must include fast-growing, multipurpose (MPFG) trees that have the following qualities: survive in full (12 hour) sunlight; have a strong taproot (as opposed to an extensive lateral root system); produce wood that is useful for both construction and fuelwood, be very coppiceable (meaning that it grows back vigorously when cut); and have leaves that can be used either as animal forage, organic fertilizer, a natural insecticide, or other use. These trees should preferably be nitrogen fixing trees.

As for the exact species for your region, you must ultimately make that decision. Discuss species selection with other technicians and staff of your local department of forestry or natural resources if you have any questions. For land reclamation and establishment of agroforestry systems world-wide, Trees for the Future has seen great success using *Leucaena leucocephala* (p.36). Other popular agroforestry species, examples of which are on pages 37-47 of this training packet, have also proven very useful in agroforestry systems around the world. Here is a list of some of our favorite (sub)tropical MPFG species. We keep stocks of seeds of many of these tree species at our seed distribution sites around the world. After passing the agroforestry test, you will be eligible to submit a request for seeds. For more information on tree species, visit the technical training and education materials posted at www.plant-trees.org.

Acacia albida (thorny)	Leucaena leucocephala
Acacia angustissima	Leucaena salvadorensis
Acacia mangium	Moringa oleifera
Acacia nilotica (thorny)	Paraserianthes falcata
Acacia senegal (thorny)	Prosopis juliflora (thorny)
Acrocarpus fraxinifolius	Senna siamea
Albizia lebbek	Sesbania grandiflora
Azadirachta indica	Sesbania sesban
Calliandra calothyrsus	Ziziphus mauritiana (thorny)
Cassia fistula	<u>Temperate trees:</u>
Gliricidia sepium	Gleditsia tricanthos
Leucaena colinsii	Robinia pseudoacacia



Read the following pages to help you identify species that will best help your communities.

Lesson 8: Agroforestry Tree Species - *Leucaena*

(Fr.) *Leucaena*, (Sp.) *Guaje*, (Eng.) *Leucaena*, (Swahili) *Mbaazi*

Overview: Fast growing, deciduous small tree or shrub, reaching up to 20 m tall. Native to the American tropics, improved varieties of *Leucaena* are now being developed on nearly every continent. It is predominantly self-pollinating and therefore gives forth offspring similar to the mother tree. Use of *L. colinsii* and *L. salvadorensis* is mostly in Central America.

Agroforestry Uses: **FERTILIZER:** Leaves are high in nitrogen and are great as an organic fertilizer. **WINDBREAKS:** Good, tall filler in windbreaks because leaf density is full yet not too thick, space ~3-4 meters apart. **LIVE FENCING:** Fast growth speed makes it great for live fence posts as long as animals do not eat the seedlings before they mature. **WOOD:** Coppiceable, dense wood good for fuelwood and pole timber. **ANIMAL FORAGE:** The high protein quantity and the sheer amount of leaves (pic 8A) well into the dry season make it a great source of forage. However, it contains mimosine, an irregular amino acid, and should be fed in limited amounts to non-ruminant / single stomach animals (none at all to horses or mules). For ruminant animals (cattle, goats, sheep), it can be fed from 20-30% of the diet. Lesson 4, page 27, has more details. **ALLEYCROPPING:** Nitrogen fixing; can be planted on flat terrain or in contour lines on slopes, *Leucaena* makes great hedge rows that produce organic fertilizer, pole timber, and serve as windbreaks. **FUEL:** Quality fuel and charcoal.



Leucaena tree form



Characteristics: Growth rates are fast, and crown shape and branch formation are all similar. Narrow canopy up to 20 meters tall, sometimes higher. Very coppiceable. *L. colinsii* and *L. salvadorensis* have very similar properties as *L. leucocephala*.

Site Requirements: Grows best in full sun, though can handle partial shade. Tolerant of many types of soil and terrain, but tends not to fare well in acidic soil. Can tolerate light frost though will likely be defoliated.

L. leucocephala: Altitude 0-1500 m; Rainfall 650-3,000 mm

L. collinsii: Altitude 100-900 m; Rainfall 500-1,000 mm

L. salvadorensis: Altitude 200-1000 m; Rainfall 800-2,000 mm

Propagation: *L. leucocephala*: Soak in boiled water for 2 minutes, then add cool water. Soak for 24 to 72 hours. Another option is to scarify the seed coat. Make sure not to damage the radicle/embryo (the pointed side of the seed). *L. collinsii*: Soak in boiled water for 30 seconds, then add cool water. Soak for 24 to 72 hours. Scarification is more effective. Make sure not to damage the radicle/embryo (the pointed side of the seed). *L. salvadorensis*: No pretreatment required

Pests and Diseases: A myriad of insects, fungi, and animals attack *Leucaena*, yet few cause serious damage. Widespread leaf loss from psyllids in the mid-1980's is less of a concern for new, more resistant varieties. Adult trees have very few problems, though seed loss by seed weevils and flower loss by moth larva have been reported. Grazing animals are by far the greatest problem!

Lesson 8: Agroforestry Tree Species - *Calliandra calothyrsus*

(Fr.) Calliandre, (Sp.) Cabello / Palo de ángel, (Eng.) Red calliandra, (Swahili) Mkaliandra

Overview: Native to the uplands of Indonesia and Latin America, *Calliandra* produces excellent firewood. Leaves are high in nitrogen and are used as a fertilizer and sometimes as livestock fodder. In tropical areas it can be established at elevations above 2000 meters but develops best below 1300m. Great pioneer species used to reclaim over-used lands.



Agroforestry Uses: WOOD: Branches tend not to be good sources of pole timber, but excellent for coppicing and fuelwood production. Great for domestic cooking and fueling small kilns, ovens, and dryers. Woodlots usually spaced 1m x 1m or 2m x 2m. Should be coppiced at 20-50cm above the ground to facilitate resprouting and prevent fungal infections. SOIL IMPROVEMENT/LAND RECLAMATION: Thrives on slopes, marginal soils, and degraded agricultural land. Improves soil by fixing nitrogen and leaf litter. Great for alley-cropping (pic 8C) BEE FODDER: Nectar-rich flowers great for year-round honey production (pic 8B). FORAGE: 22% protein, high tannins, no toxic components. Liked by cattle and goats in Indonesia.

Characteristics: Vigorous nitrogen-fixing, bushy tree. Fast growth rate to 4-6 meters tall (known to reach 12m), growth of 3-5 meters is possible in the first year. Branches tend not to develop into straight poles. Crown is moderately heavy and sheds leaves in seasonal climates. Has both superficial and deep-growing roots.

Site Requirements: Good in humid tropics, tolerates rainfall as low as 700mm, but thrives in areas with 2000-4000mm. Avoid areas with poor drainage where waterlogging occurs. Prefers light soil textures and slightly acid conditions, but can grow in a wide array of soil types. Tolerates altitudes from 250 to 1800 m. Moderately shade tolerant. Moderately drought resistant, but during severe drought the tree will die off and come back with the rains.



Propagation: PLASTIC SACKS: Pretreat seeds by soaking in boiled water. Let the water cool and soak the seeds for 24 hours. Seed 2 per sack, cover with ¼ inch of soil and keep moist. Outplant at 20-50cm height, when root collar is 0.5-1.0cm. STUMPING: Plant pretreated seeds in nursery bed, allow to grow to 75-100cm which takes about 4 months. When ready to outplant, prune the roots at 20 cm and the top at 30cm, strip leaves. Stumps can be stored for up to a week if kept moist. Whether propagated with sacks or as stumps, weeds should be cleared before planting and monitored during the first year. When reclaiming poor soil, trees respond well to fertilizer (phosphate) in the first year. BARESTEM: See Lesson 10.

Pests and Diseases: *Calliandra* tends not to suffer from major pests or diseases. Mature trees should be coppiced cleanly 50cm above ground to avoid infestations in the fissures of harvested stumps.

Lesson 8: Agroforestry Tree Species - Sesbania

S. sesban- (Sp.) Tamarindillo, (Eng.) Common sesban, Egyptian rattle pod, riverhemp
S. grandiflora- (Fr.) Colbri vegetal, fleur papillon, (Sp.) Cresta de gallo, (Eng.) Vegetable hummingbird

Overview: Thought to be originally from Egypt, *S. sesban*, a short nitrogen fixing tree, is great for animal fodder and fuel-wood. *S. sesban* (pic 8D) and *S. grandiflora* (pic 8E) share many qualities, though *S. sesban* is better for drier climates.

Agroforestry Uses: Difficult to establish in highly-grazed areas because it is favored by animals. **FORAGE:** Leaves are a good source of protein for cattle and sheep (Berhe, et al, 1999). **WOOD:** Coppiceable; light wood is good for cooking; yields excellent charcoal; branches and stems used for light construction. **ALLEYCROPPING:** Can be intercropped with corn, beans, cotton and many other field crops. Serves as a support for grapes and black pepper. Also used as a shade tree for coffee and tumeric. Grown as a support for sugarcane, each plant bracing six canes. **SOIL RECLAMATION:** Planted on fallow land for soil improvement. Harvested leaves make a rich compost. **WINDBREAK:** Applicable around vegetable gardens, but often too short for protecting large crop fields.

Characteristics: Fast growing, short-lived tree. Grows many branches. Tends to develop into a shrub or small tree about 4 to 15 meters tall. Flowers for either species can be pink, purplish, white or red.

Site Requirements: Tolerates saline, acidic, or waterlogged soils. Prefers between 500 and 2000 mm rainfall. *S. sesban* is able to grow at elevations between 100 and 2300 meters.

Propagation: **SEEDS:** Very susceptible to insect attack and should not be stored for over 1 year. Seed 2 seeds per sack 12 weeks before outplanting. Weeding around seedlings recommended in the first month after outplanting. Barestem propagation possible but not thoroughly tested.

S. sesban: Scarification is recommended. Make sure not to damage the radicle/embryo (the pointed side of the seed).
S. grandiflora: Scarification helpful, or soak in cold water for 24 hours. Make sure not to damage the radicle/embryo (the pointed side of the seed).

Pests and Diseases: The seed is commonly attacked by insects. Leaves and branches are susceptible to attack by caterpillars, weevils, bacteria and fungi. Burn infested plants.



Lesson 8: Agroforestry Tree Species - Cassia and Senna species

C. fistula- (Fr.) Casse doux, espagnole (Sp.) Canâfistula mansa, Chácara (Eng.) Golden shower, Indian laburnum
S. siamea - (Fr.) Casse de Siam, (Eng.) Black-wood, Yellow cassia, (Swahili) Mjohoro

Overview: *Senna siamea* (pic 8F & 8G) is a fast growing evergreen native to Southeast Asia. It tolerates both arid lands and tropical climates. Because of its fast growth and quick regeneration from coppicing, it is applicable to many agroforestry systems. It is very popular in arid regions, particularly West Africa. *C. fistula* (pic 8H) is not as widely used in agroforestry as *S. siamea* and tends to be less tolerant of dry conditions.

Agroforestry Uses: Leaves are high in nitrogen and great as an organic fertilizer. **WINDBREAKS:** Good, tall filler in windbreaks, space at 3-4 meters. **LIVE FENCING:** Growth speed makes great live fence posts. **WOOD:** Dense wood, great for fuelwood and pole timber, very coppiceable. **BEE FODDER:** *C. fistula* is popular with bees. **ANIMAL FODDER:** Leaves are highly toxic to pigs but are an excellent source of forage for ruminant animals. **DISPERSED TREE:** Good for shade around houses, roads, schools.

Characteristics: Rainfall as low as 500mm may inhibit growth from exceeding 5 meters, yet rainfall up to 1500mm can allow growth to 20m. Lateral roots have been reported to compete with crops in alley cropping, so should be kept out of gardens and crop fields (though makes a great windbreak/boundary planting). Seeds all year round. Produces large quantities of biomass, but does not fix nitrogen.

Site Requirements: The dry season cannot exceed 8 mos. **SUN:** Enjoys full sun. **SOIL:** Decent soil is sufficient, but cannot tolerate poor or skeletal soils.

C. fistula: Altitude 0-1200 m; Rainfall 480-2,700 mm

C. siamea: Altitude 0-1200 m; Rainfall 400-2,720 mm

Propagation: Be sure not to seed too deep (only ~1/2 cm deep). Seed 4-5/sack if hot soaked and 3-4/sack if scarified by hand. Keep soil moist and in a sunny place. Propagation by cuttings up to 2 meters in length is possible. Weeding is necessary for the first one or two years of growth during which they require pruning to develop a straight trunk.

C. fistula: Scarification. Make sure not to damage the radicle/embryo (the pointed side of the seed).

S. siamea: No pretreatment required.

Pests and Diseases: Insects are quick to attack harvested or splintered wood.



Lesson 8: Agroforestry Tree Species - *Grevillea robusta*

(Fr.) *Grevillée robuste*, (Eng.) *Grevillea*, Silk oak, (Swahili) *Mgrivea*

Overview: Fast growing evergreen timber tree native to the Pacific Islands and Eastern Australia. Very popular in East Africa and growing in popularity in Central America. Grows well in tropical highlands and lowlands.

Agroforestry Uses: Great for reforestation. **WOODLOTS:** Good for medium strength poles and fuelwood, coppice-able. Plant in woodlots (2.5 m x 2.5 m) and rows (2-2.5 m between trees). Harvest branches by pruning high, leave about 1/3 of the branches after pruning to support regrowth. **BEE FODDER:** Nectar-rich flowers are great for honey production. **WINDBREAKS:** Space at ~3 meters and combine with shorter species. **FERTILIZER:** High leaf litter (pic 8K), good source of natural mulch. **INTERCROPPING:** Good shade-species for tea and coffee. Cut roots around trunk to 30cm whenever planted next to crops to minimize competition from *Grevillea*'s root systems (Kalinganire, 1996).

Characteristics: Fast growing, to 8-9 meters in 5 years (Tesfaye et al, 2004). Grows up to 18-30 meters. Complex, shallow root system allows for efficient nutrient uptake, even in poor soils. Leaves produce a chemical that inhibits growth of other plants, but no major problems regarding this issue has been reported.



Site Requirements: **WATER:** Found in both dry and wet climates (600-1,700mm). Fairly drought tolerant, as little as 350mm rainfall can support growth. **ALTITUDE:** Grows at sea level to 2300 m. Can tolerate light frosts. **SOIL:** Grows in neutral to highly acidic soils (best in slightly acidic), well-drained soil preferred. **LIGHT:** Not very shade-tolerant, flowers best in open, sunny areas.

Propagation: Extreme heat may hinder germination rate. **SACKS:** No pretreatment is required. However, seeds can be pretreated by putting them in a bowl of boiled water and allowing them to cool for 24 hours. Seed in sacks 1/2 cm deep and keep the soil moist. **CUTTINGS:** Place cuttings 7.5-10cm long in sacks about 3.5 cm deep. Leave only a few leaves near the top of the cutting.

Pests and Diseases: Not prone to any specific pests or diseases. Susceptible to fungi in low, humid areas. In the Caribbean, often attacked by scale insects.



Lesson 8: Agroforestry Tree Species - Albizia and Paraserianthes species

A. lebbeck- (Fr.) Bois noir, (Sp.) *Acacia amarilla*, (Eng.) Woman's tongue, (Swahili) Mkingu, (Cr.) Tcha tcha, *P. falcata*- (Eng.) Albizia

Overview: Native to India, sub-tropical Africa, Asia, and northern Australia, Albizia trees are now widely cultivated throughout the tropics. *Albizia lebbeck* (pic 8L) is very suitable for the southern sahel. *Paraserianthes falcata* (pic 8M) is a fast-growing hardwood.



Agroforestry Uses: SOIL: Nitrogen-fixing tree, produces green manure. INTER-CROPPING: Good companion plant for coffee and tea. WINDBREAKS: Good for shelterbelts, but not in areas with little to no precipitation. FODDER: Leaves, flowers, and pods make good fodder. TIMBER: Coppiceable, good for fuel wood and carpentry, though difficult to work. BEE FODDER: Large 5cm-long flower heads are attractive to bees. OTHER: Finely pounded bark used in soap-making. Good for roadside and village plantings.

Characteristics: Medium-sized deciduous tree, usually 6-12m high, fast growing. Can reach 30 meters in areas with high precipitation. Tolerates light frost.

Site Requirements: SUN: They grow best in full sun, but will tolerate partial shade. SOIL: Prefers loamy soils, but can grow on sandy, weathered soils. Tolerates acid and alkaline soils, as well as salt spray.

P. falcata: Altitude 1-1200 m; Rainfall 2,000-4,000 mm

A. lebbeck: Altitude 0 -1,800 m; Rainfall 500-2,500 mm

Propagation: Sow 2 seeds/pot, 15-18 weeks in the nursery in partial shade before transplanting to beds at beginning of rainy season. Can be propagated by cuttings and root suckers. Barestem propagation should be applicable. *P. falcata*: Soak in boiling water for 3 minutes, then add cool water and soak for 24 hours.

A. lebbeck: Scarify, making sure not to damage the radicle/embryo (the pointed side of the seed) and then place in boiled water. Let water cool and soak the seeds for 24 hours.

Pests and Diseases: Susceptible to damage from high winds and from attacks by insects and rodents .



Lesson 8: Agroforestry Tree Species - *Moringa oleifera*

(Fr.) *Ben ailé*, (Eng.) *Horse-radish tree*



photo taken by Harvey McDaniel

Overview: Moringa has been referred to as "Nebeday" for its strength and tendency to "never die". It is popular in backyards throughout Asia, Africa, and Central America.

Agroforestry Uses: **FOOD:** Leaves, young pods (pic 8Q), flowers, and horseradish-tasting roots are all edible, and are sometimes used in salads. Very high in Vitamin A & C, calcium, protein, iron, potassium, magnesium, and other vitamins and minerals. Leaves are usually cooked in sauces for vitamins. Nutritious tea is made with the leaves for pregnant women and children. Leaves, dried in the shade and pounded, can be mixed with peanut butter, chocolate spread, or any

other food as a vitamin additive. **WOOD:** Soft, spongy wood is very coppiceable but not a great source of wood for building or firewood although it is sometimes used. **FENCING:** Straight trunks make good living fence posts. Can make live fences when spaced at 15-20 cm. Makes a good dispersed tree in fields, gardens, or family compounds. **OTHER:** Powder from crushed seeds can be used to coagulate and settle dirt/bacteria out of water for purification.

Characteristics: Very fast growth rate. Tends to have an open, undeveloped crown. Branches easily break during leaf harvesting, leads to stunted growth about 3-4 meters tall, though can reach 8m. Branches tend to be spindly.

Site Requirements: **WATER:** Strong tap root, highly drought resistant, but requires at least 500 mm of rainfall. **SUN:** Likes a lot of direct sun, yet is known to survive mild frost. **SOIL:** Prefers neutral to slightly acidic sandy soils though tolerates a wide range of conditions. **ALTITUDE:** Grows between 0-1000 m in elevation.



A field of three-week-old *Moringa* trees planted like a field crop for leaf production

Propagation: Naturally regenerates well. Cuttings between 20cm and 4m can be used, be sure of orientation when placing cuttings in soil/sacks. Direct seeding does very well, seeds require no pretreatment. Fresh seed will sprout in 3-5 days. Also sown in sacks, cover with ~1cm soil. **LEAF PRODUCTION:** (pics 8O & 8P) Seed Moringa in a bareroot bed with ~3cm between seeds, do not outplant, harvest 1/2m tall seedlings by cutting them about 10cm from the ground, keep bed moist and all seedlings will regrow for continued leaf harvests. **BARESTEM:** Barestem propagation methods are often used (Lesson 10).



Pests and Diseases: No major problems reported

Lesson 8: Agroforestry Tree Species - *Gliricidia sepium*

(Fr.) *Immortelle*, (Sp.) *Madre de cacao*, (Eng.) *Gliricidia*

Overview: *Gliricidia* is a nitrogen fixing tree known throughout the Americas as "Madre de Cacao" or "Madera Negra". Because of its high output of hard wood and rich leaf litter, it can play a major role in agroforestry systems.

Agroforestry Uses: **FUELWOOD:** Good quality. **TIMBER:** Strong wood used in heavy construction, tools, posts, and furniture. **BEE FODDER:** Good for supporting honey production. **FORAGE:** Leaves not widely used for animal forage because some animals dislike the taste, but palatability improves when leaves wilt overnight (pic 8R). **FERTILIZER/ALLEYCROPPING:** Great source of green manure and leaf litter. Leaves have a high concentration of nitrogen, when submerged in water for 20 days they produce a strong natural fertilizer. Easy to establish as an alleycrop. **LIVING FENCE** (pic 8S):



8S



8R

Though lacking thorns, it is relatively easy to establish hedges, especially when propagated by cuttings. **OTHER:** Mix mashed seeds or boiled bark with food bait to kill rodents.

Characteristics: Very fast growth rate, possible to reach 4.5 meters in a few months from cuttings. Known to have strong lateral root system that can sometimes inhibit growth of surrounding vegetation. Flowers are usually pink (pic 8T).

Site Requirements: **RAIN:** Prefers over 1000 mm yet can survive with as little as 700 mm, not drought tolerant. **SOIL:** Tolerates salinity and many soil types.

Propagation: **SACKS:** No seed pretreatment. Seed 2 per sack 8-12 weeks before outplanting. **CUTTINGS:** Small cuttings may be placed in sacks or directly in the ground. They



8T

may need some water during the first dry season because root structure may not be as developed as those started from seeds. Larger cuttings, 15cm wide and 2 m long, allow for fastest growth. Scrape the base of the cutting to encourage rooting. Place 2 m cuttings ½ m in the ground a couple weeks before heavy rains begin.



Pests and Diseases: Not a target of any specific pests, though reported to be one of hundreds of plants that host the pink hibiscus mealybug, a serious (sub) tropical pest around the world.

Lesson 8: Agroforestry Tree Species - *Prosopis* species

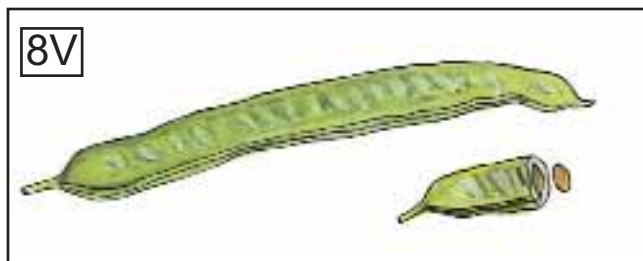
(Fr.) Bayarone, (Sp.) Algarroba, (Eng.) Mesquite, (Swahili) Kikwajukwaju

Overview: *Prosopis juliflora* (pic 8U) is a highly esteemed fuelwood source in several tropical countries. It is also valued for the shade, timber, and forage it provides, and it fares well in dry regions.

Agroforestry Uses: **FUELWOOD:** *Prosopis* wood is hard and heavy. It is excellent for firewood and makes superior charcoal. It burns slowly and evenly and holds heat well. **DUNE STABILIZATION:** Because it thrives in sandy, arid areas, *Prosopis* has been successfully used for dune stabilization in places such as India. **LIVING FENCES:** *Prosopis* contributes well to living fences. Trees must be pruned early in development to encourage lateral branching. Very coppiceable, so branches help fill in living fences. Thorns are sharp but branches are still workable (unlike some *Acacia* species). **WIND-BREAK:** *Prosopis* trees are not very tall, but they are still successfully used in windbreaks for smaller fields or to fill in lower tiers of windbreaks. **FORAGE** *P. juliflora* drops massive quantities of seed pods which sheep and goats enjoy eating (pic 8V).



Characteristics: A thorny, deciduous tree, large crown, deep roots. *P. juliflora* may grow to 10 meters or more. Other species are shorter. Dark green leaflets (pic 8W) are very small and quickly degrade. Seed pods are long and thin. Some introduced *prosopis* species have become invasive, and so use should be carefully considered.



Site Requirements: Grows well in hot, dry climates. Not frost hardy. Prefers altitudes from sea level to 1,500 meters. Drought tolerant - grows in areas with 15-750 mm rainfall, and in a variety of soils, including on rocky terrain.

Propagation: Reproduces easily by root suckers and seeds. Seeds require scarification on a rough surface to penetrate hard seed coat. **PLASTIC SACKS:** Plant 3-4 seeds per sack. Competes well with weeds. Barestem propagation has not yet been tried.

Pests and Diseases: Bruchid beetles often damage much of the seed crop in certain regions.



Lesson 8: Agroforestry Tree Species - *Azadirachta indica*

(Fr.) Nim, (Sp.) Nim, (Eng.) Neem, (Swahili) Kohomba

Overview: Originally from India and Burma, this broad-leaved evergreen and cousin of mahogany is now used throughout the world (pic 8X).

Agroforestry Uses: **WINDBREAKS:** With 4m spacing, creates a great windbreak. **WOOD:** Begins producing timber after 5 years. Best if coppiced 1.5 or 2 meters height. Major source of straight poles (pic 8Y). **SOIL RECLAMATION:** Tolerance to most soil conditions, high survival rate, and resistance to grazing animals make neem a solid pioneer tree for reforesting lands, delineating field crops, or trying to establish any type of border planting (ie windbreak, living fence). **SHADE:** Used for shade in family compounds and along roads. **PESTICIDE:** (see

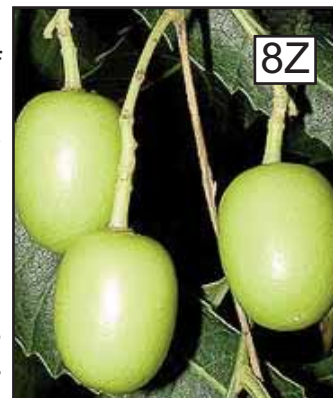


page 27) Submerge leaves and crushed kernels (pic 8Z) in water overnight to make a great natural pesticide. Neem has over 20 active chemicals, the most important of which is azadirachtin, which help to repel and distort the reproduction cycles of numerous insects, nematodes, fungi, bacteria, and even viruses. Solution should be applied once every week on garden vegetables, field crops, and tree nurseries. Leaves can be used when making soap to give it antimicrobial and insecticidal properties. Warning: direct sunlight on leaves will destroy the pesticide ingredient. Neem is NOT poisonous to humans. **BEE FODDER:** Clusters of small white flowers attract many bees. Pesticides are not present in the honey (National Research Council, 1992).

Characteristics: Up to 30 meters tall, trunk usually not thicker than 1 meter. Very fast growth rate, up to 6 meters in a year. Very coppiceable. Neem tends not to be planted among gardens or alley-cropped with field crops because it absorbs a lot of water and may outcompete other plants. Seeds often dispersed by birds and fruit bats that eat the sweet yellow fruit around the seed kernels.

Site Requirements: Grows almost anywhere. **RAIN:** Prefers 400-1200mm of rainfall but can tolerate both drought and higher rainfall. Waterlogging can kill trees. **ALTITUDE:** Sea level to 700m, and as high as ~1000m around the equator. **SOIL:** Neem can withstand dry, infertile soil, as well as acid soils. Slightly salt-tolerant. **TEMPERATURE:** Thrives in extreme heat, but dies in freezing temperatures.

Propagation: **SEEDS:** Normally do not store well over 6 months. Seeds should be cleaned with water to improve germination. No pretreatment necessary. Seed in sacks 12 weeks before outplanting. Barestem and direct seeding is successful. Cuttings possible, but propagation by seed is most common.



For more information: Read "Neem" in the Agroforestry CD

Lesson 8: Agroforestry Tree Species - Acacia species

A. angustissima- (Sp.) Timbre, (Eng.) Fern acacia

A. mangium- (Sp.) Zamorano, (Eng.) Black wattle

Overview: Known for their hardiness in dryland Africa, Acacia species are actually very diverse and are native to most regions around the world. Many of the popular agroforestry species are not thorny, though many Acacia species, especially those in Africa, have evolved thorns as a method of protecting themselves from browsing, and thereby conserving water.

Special Assignment: Read pages 123-152 of the book entitled “Acacias for Rural, Industrial and Environmental Development.” This book is on the CD that comes with this training manual. It is an older resource, but it does a good job of discussing the main Acacia species that we at Trees for the Future encourage communities to plant.



Acacia angustissima



Acacia angustissima



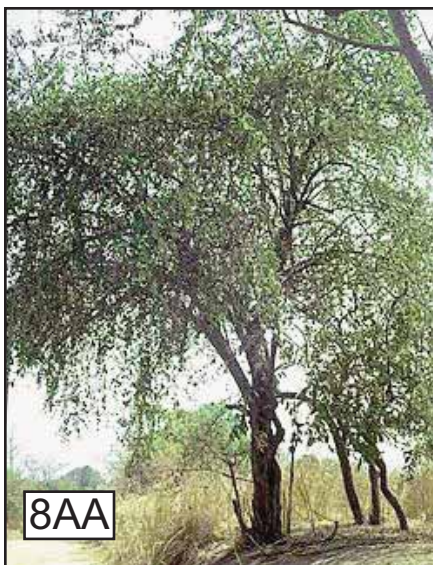
Acacia nilotica



Acacia mangium

Lesson 8: Agroforestry Tree Species - *Ziziphus mauritiana*

(Sp.) *Perita haitiana*, (Eng.) Chinese date, (Swahili) Mkunazi, (Wolof) Jujube, (Hindi) Ber



Overview: The genus *Ziziphus* belongs to the Rhamnaceae family, and has about 100 species of deciduous or evergreen trees and shrubs distributed in the tropical and subtropical regions of the world (pic 8AA). The fleshy seed coat of several species are rich in sugars and vitamins, and this fact has made *Ziziphus* species important fruit trees for many centuries.

Agroforestry Uses: **LIVE FENCING:** The trees are excellent for live fencing. When coppiced, the branches grow laterally and can easily woven with neighboring branches. The sharp thorns deter most animals. **SOIL STABILIZATION:** Planting *Ziziphus* reduces the rate of desertification and soil erosion in deserts by stabilizing sandy tracts and dunes. **FODDER:** The leaves and twigs can be used as high nutritional fodder for livestock. **WOOD:** Excellent fuel-wood tree and makes a good charcoal. **FOOD:** Fruits of all *Ziziphus* species are edible (pic

8AB). The drupes are eaten fresh, pickled, or dried and the juice can be made into a refreshing drink. Fruits are sold on local markets and consumed at household. **MEDICINAL USES:** Fruits are applied on cuts and ulcers, employed in pulmonary ailments and fevers, and sometimes mixed with salt and chili peppers to be given for indigestion. The seeds are sedative and are taken, sometimes with buttermilk, to halt nausea, vomiting, and abdominal pains in pregnancy.

Characteristics: *Z. mauritiana* is a vigorous grower and has a rapidly-developing taproot. It may be a bushy shrub 1.2-1.8 m high, or a tree 10 to 30 meters; erect or wide-spreading, with gracefully drooping branches and downy, zigzag branchlets, thornless or set with short, sharp straight or hooked spines.

Site requirement: *Ziziphus* lives in a wide range on climates.

ALTITUDE: It is found in altitudes between 300-1000m.

RAINFALL: Prefers annual rainfall ranging from 120 to 2200mm but the tree is drought resistant and can survive salinity and waterlogging. **SOIL:** The best soils are sandy loam which may be neutral or slightly alkaline, but it will grow on a wide variety of soils. It is also able to survive injury and fire damage.

Propagation: No pretreatment is needed, but storage of seed for 4 months before sowing improves germination. Will germinate in 3-4 weeks if you remove fleshy seed coat and crack hard outer shell before sowing. For fastest germination, extract the internal seed from the hard shell. This is easiest done utilizing a mortar and pestle. Be care, though, not to damage the fragile seeds in the process. **SACKS:** Sow 3-4 seeds per sack. Seeds require full sunlight to germinate, and seedlings should be grown in full sunlight.



Pest and Disease: The greatest enemies of the jujube in India are fruit flies, *Carpomyia vesuviana* and *C. incompleta*. It has been found that treatment of the ground beneath the tree helps reduce the problem.

Lesson 9: Seed Collection, Storage, and Pretreatment

Lesson Objective: By the end of Lesson 9, YOU will be able to: 1) list the 7 major guidelines in seed collection; 2) briefly explain important steps in processing seeds; 3) list and explain the 5 major factors in seed storage, and 4) explain why and how we pretreat seeds.

Seed Morphology & Function of Seed Components (figure 9A)

Radicle - the plant's complete root system develops from these cells. All seeds have some type of point or bulge that is the radicle.

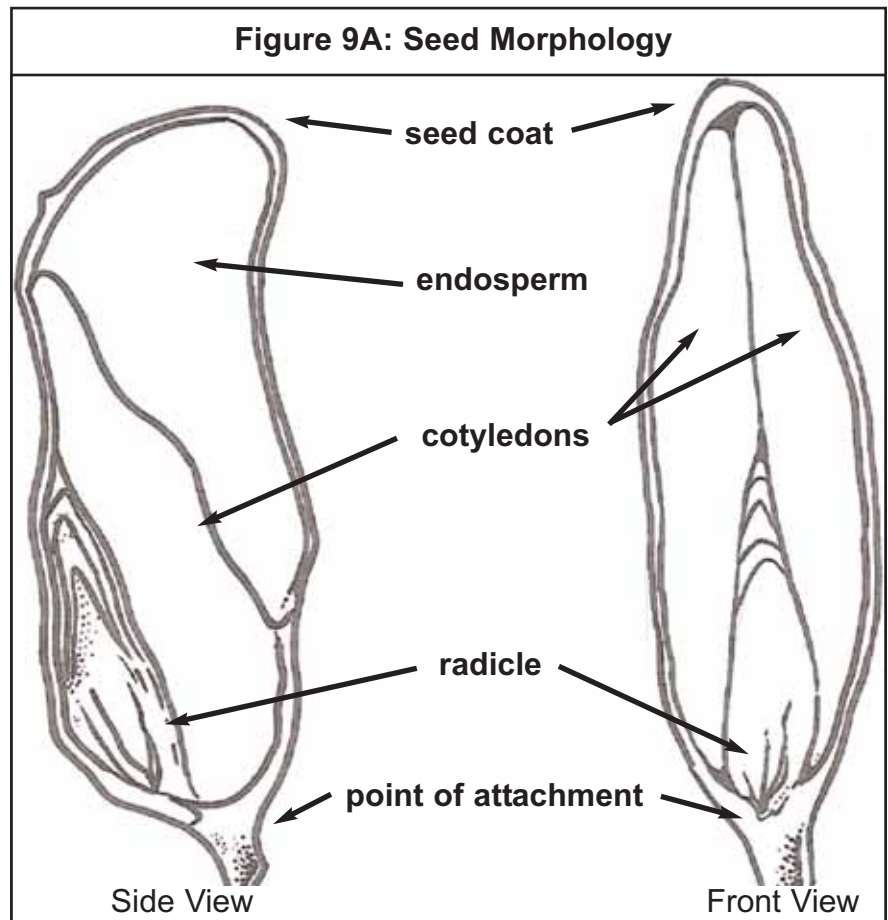
Cotyledons - these are the first 'leaves' seen when a plant emerges. They are generally waxy and look different from true leaves that emerge later

Endosperm - the food for the seed

Seed Coat - protects the seed embryo, the living part of the seed

Germination / Pretreatment

Most forestry tree species require pretreatment to induce germination (moringa is one notable exception). Pretreatment refers to techniques that help water enter through the hard seed coat. Page 50 demonstrates a hot water soak which is an appropriate pretreatment for most seeds.



Seed Selection and Collection Guidelines

- Identify the parent trees for trunk/branch formation, resistance to pests/diseases, & growth rate.
- Collect seeds of the same species from sites separated by over 100m to ensure genetic diversity.
- Avoid trees that are isolated from others of the same species. This limits genetic diversity.
- Harvest only mature seed from ripened fruits. Fruit sold in markets is often harvested before ripening, and so fruit from markets may not be a good seed source
- To ensure genetic variation, collect fruits equally from all parts of the tree's crown (top, sides, and bottom), as these parts may have been pollinated at varying times from different sources. Use long sticks or rakes to reach seeds in high places.
- Collect throughout the full natural range of habitat. Include trees that cover environmental extremes.
- Man-made stands like live-fencing, plantations, or windbreaks should be utilized with caution.

How We Process Seeds

Step 1: Remove husks. This is done in order to remove insects that make the husks their homes. Also, husks are home to larvae, attract many pests, and make seeds bulkier to store.

Step 2: Pick out bad seeds (e.g. disfigured or irregular formed seeds, boring insects, etc.),

Step 3: Dry in shade after washing/removing leftover fruit membrane

Step 4: Prevent rot by avoiding moisture build-up in storage (air out regularly, store in good location).

Lesson 9: Seed Collection, Storage, and Pretreatment

Major Considerations for Storing Seeds

a. Moisture

Moisture causes rot. Make sure seeds are dry when placed in storage. Remove lids once per month to expel built up moisture and to also check for larvae which could have hatched.

b. Temperature

Keep seeds in a dark, cool place. Some species cannot survive in temperatures above 40°C. Fruit tree seeds should be refrigerated and may only be stored for a short time. Other seeds, such as Acacia seeds, may be stored in cool places for several years (Teketay, 1996).

c. Atmosphere

Containers should be kept off floors and away from walls due to insects and dampness.

Place containers where air can circulate around them; this helps with cooling and dryness.

d. Containers

Plastic, glass, and metal containers all have their pro's and con's. Just be careful and try to avoid: 1) breakable containers, 2) containers that let in a lot of light, and 3) containers that mice can chew through. Use some ash and/or insecticide to protect the seeds from pests.

e. Knowledge

For all seeds you store, be sure to label the container or bag with name, collection date, place of origin, name of collector, and the date when seeds should be pretreated and sown.

Germination is influenced by the following external factors (specific to each species)

- a. Alternate heating and cooling (even fire)
- b. Alternate wetting and drying
- c. Sensitivity to day length or light
- d. Passage through and animal's digestive tract
- e. Activities of soil organisms, fungi, insects

Why is pretreatment required?

- a. All seeds must absorb water to germinate
- b. Some seeds have waxy seed coats that keep them from absorbing water
- c. Some seeds have hard, thick seed coats that keep them from absorbing water
- d. Pretreatment assures that all seeds in a nursery germinate at the same time

Types of Pretreatment

- a. **hot water soak** - Boil water and pour hot water onto the seeds. Usually from 4-48 hours; generally, seeds with harder coats. (Acacias, Leucaenas, Albizzias and others)
- b. **cold soak** - air dry seeds, then soak them in cold water before planting (Neem, Papaya)
- c. **clipping and/or scarifying** - use nail clippers, rocks, or other coarse surfaces to break/scratch/cut the seed coat. Clip the seed coat until you see the white interior. (Leucaena, Acacia, Delonix regia).
- d. **acid bath** - dip in sulphur - this technique is not popular. Many communities feed seed pods to animals and collect the manure, spreading it on fields where they want the trees to grow.

DO NOT FORGET:

- 1) **Seeds will swell when pretreated in water - don't plant any seeds until they begin to swell!**
- 2) **Every seed has a radicle, a small bump or point visible from the exterior of the seed. Roots grow from the radicle - don't damage the radicle!**

By pretreating seeds, we imitate nature's methods of breaking seed dormancy

Lesson 10: Bareroot Nurseries & Barestem Seedlings

Lesson Objective: By the end of Lesson 10, YOU will be able to: 1) cite four benefits to the barestem method and 2) identify the dates when bareroot nurseries should be started in your community.

Around 1979, Trees for the Future stopped using plastic bags to grow seedlings of many species, for several reasons.

- (a) The bags cost a great deal of money, both to purchase them and the labor to fill them.
- (b) Transporting bags holding 1.5-2 kg of dirt from the seedbed, to the planting site, and often up steep hills, and then digging large holes, requires a great amount of unnecessary labor.
- (c) The bag limits the size of the seedlings so there is less growth in that initial, very important, rainy season.
- (d) The nursery area where the seedlings are grown is much larger and therefore requires far more water for daily irrigation.

We further noted that with good seedbed management, larger and stronger seedlings are being produced through the barestem method. Therefore the survival rate has been higher, averaging about 91% as compared to about 85% with plastic bags.

A seedbed nursery should be located near the house of the family tending it, and also close to a source of water, because daily watering in the late afternoon is very important (Evans, 1992: 122-170). We recommend that the bed be "double dug", that is, the soil should be loosened down to about 30 cm in the ground, to get the strongest root systems. As it is dug, compost and/or animal manure should be added. If the soil is acidic, some agricultural lime should also be added.

There is a fungus that attacks young seedlings under very humid conditions, causing a condition known as "damping off." The primary leaves fall away and the young plant dies. In humid conditions, you should mix some fungicide with water and sprinkle this mixture on top of the seedbed.

Most tropical tree seeds have a hard seedcoat, which is nature's way of protecting them from extended drought, epidemics, and other disasters. To achieve higher success rates the seedcoats must be scarified before planting. Depending on the species, this is done by: (a) scratching them on a hard or coarse surface (be sure NOT to damage the radicle); (b) pouring boiling water over them (followed by cold water); or (c) soaking them in warm water until they begin to swell up. Then they should be placed on top of the soil and lightly covered with loose dirt (Evans, 1992: 122-170).

Most young seedlings cannot tolerate strong and continuous sunshine. For at least the first few weeks of growth, they should have partial shade. This can be accomplished by building a rack above the seedbed and laying palm fronds on it. As the seedlings get taller, this can be removed.

Because many of the desired tree species are leguminous, the soil should have nitrogen-fixing bacteria. If there are leguminous crops around, such as soybeans or mung beans, these bacteria probably already exist in the seedbed soil. If not, you can take soil from a distant field where these crops have been grown and mix it in your seedbed.

Many leguminous tree species can be planted closely together in the seedbed (for the leucaenas, we recommend planting at distances of 2-3 cm (pic 10A). In this way, we can expect to get more than 300 viable seedlings from one square meter of seedbed.



Pic 10A: After the soil has been double dug and mixed with compost, pretreated seeds are planted in equally-spaced rows. As many as 300 seedlings will grow in this square meter.

Lesson 10: Bareroot Nurseries & Barestem Seedlings

Lesson Objective: By the end of this page, YOU will be able to list the 5 steps in making a nursery.



starting your

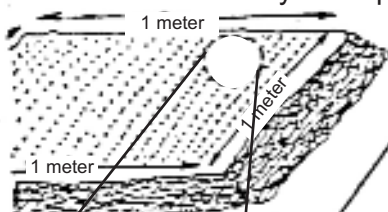
Bareroot Nursery

PLANT THE SEEDS DURING THE DRY SEASON - ABOUT 100-120 DAYS BEFORE THE RAINS ARE EXPECTED



STEP 1: PREPARING THE SEEDS

First read the propagation section for the specific seeds used. Place the seeds in a flat pan. Add enough boiling water to cover them. Wait listed time, add cool water and let soak. They will triple in size.



STEP 2: THE SEEDBED

Double-dig a raised bed, adding compost. Smooth it out. If the soil is acidic, add a little lime or wood ash. Plan to grow about 300-320 seedlings per square meter for smaller seeds.

STEP 3: PLANT THE SEEDS

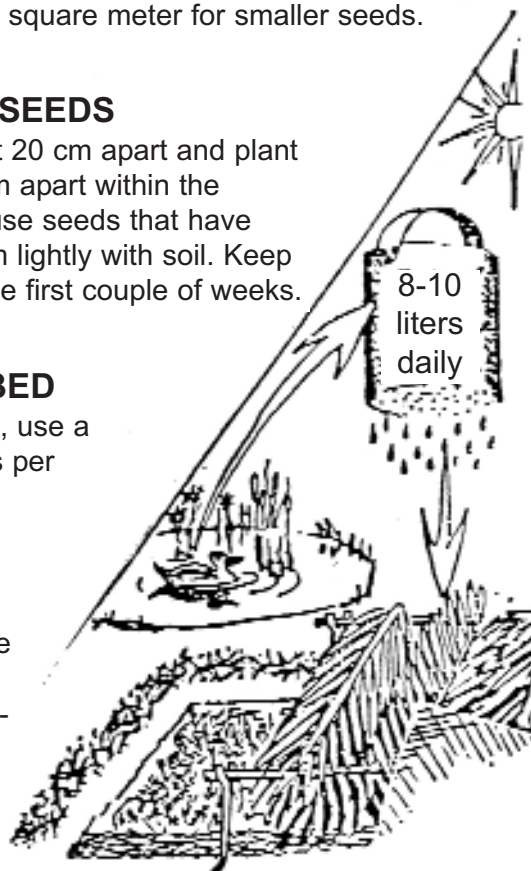
Make small trenches about 20 cm apart and plant the small seeds about 2 cm apart within the trenches. Be sure only to use seeds that have begun to swell. Cover them lightly with soil. Keep them in partial shade for the first couple of weeks.

STEP 4: WATER THE SEEDBED

Every other day toward the evening, use a watering can and provide 8-10 liters per square meter of seedbed.

STEP 5: PROTECT YOUR SEEDLINGS

Against chickens, animals, strong sunlight, and strong winds. Keep small seedlings in the shade for the first couple weeks. Build a fence around the seedbed (you can use thorny brush or whatever is available).



For more information on nursery production, there is a PowerPoint **Barestem Presentation** on the accompanying CD, as well as a copy of the book *Good Nursery Practices: Practical Guidelines for Community Nurseries* by Kevyn Wightman.

Lesson 10: Bareroot Nurseries & Barestem Seedlings

In the dry season, the dark green leaves of the seedlings in the nursery will attract livestock and wildlife, so the seedlings must be protected. Where brush is available with long sharp thorns, it can be cut and piled as a fence around the seedling nursery.

In most tropical areas, there is a distinct rainy season, ranging from 4-6 months. It's important to get the maximum growth possible in this first rainy season. **The seedbed should be established about 100-120 days before the rains are expected.** It should be watered daily and more compost should be added weekly to maximize the growth and health of the seedlings.

10B



Pic 10B: Using the barestem method, these children can easily transport hundreds of seedlings to the top of this mountain. This is what the "barestem" system can achieve: more trees, better trees, with far less labor and less out-of-pocket costs.

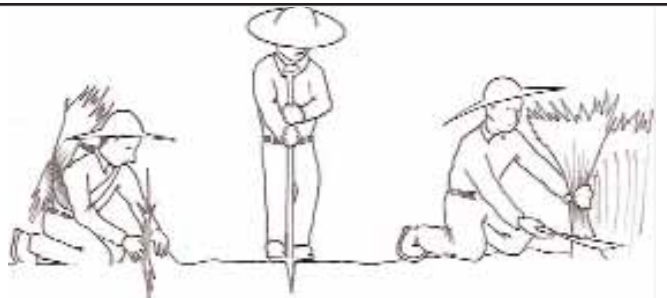
Transplanting Barestem Seedlings

Protecting hillsides and the water supply for a typical upland community will require the planting of thousands of trees, along with the labor of local families who are already working long hours to produce their food. Fortunately, much of the work of growing seedlings is in the dry season when people have more time to spare. Using the barestem system can save even more time as the trees are transplanted (pic 10B).

When the rainy season arrives, it is not necessary to transplant seedlings immediately. We mention this because this is a time of major activity for a farm family to get their food crops in the ground. During those first critical weeks, the seedlings can be left alone in the seedbed.

With these fast-growing trees, the goal is to have seedlings 1-1.5 meters tall when they are transplanted. When it is time to transplant them, the seedbed should be thoroughly soaked to the point that the tree can be pulled from the ground without damaging the roots. As they are gently pulled from the ground, they should be stripped of their branches and leaves, except for the terminal buds at the very top. There are two important reasons for removing the leaves and branches. First, it often happens that the real rainy season has not actually arrived; the winds may shift direction and there may be no rain for many days. Without leaves to desiccate from the hot wind, they remain dormant until the rains return. Secondly, root hairs break off when the seedlings are transplanted, and therefore they will not be able to provide enough water for all the leaves. Removing some of the leaves relieves stress on the roots as they become re-established.

In our experience, a team of three people working together can transplant more than 120 seedlings per hour. One man can carry a bundle of about 250 seedlings up a steep hill. One person cuts the grass where the seedlings will be planted. A second uses a heavy bar with a sharp point to punch a hole in the ground wide enough and deep enough to accommodate the root. The third person feeds the root into the hole and packs the soil around it.



Can you meet the lesson objective at the top page 50?

Lesson 10: Bareroot Nurseries & Barestem Seedlings

Lesson Objective: By the end of studying this page, YOU will be able to list the 5 steps in planting a barestem seedling.

planting your

Barestem Seedlings

DURING AN AFTERNOON, OUTPLANT THE SEEDLINGS EARLY IN THE RAINY SEASON WHEN THE SOILS ARE WET. SEEDLINGS SHOULD BE 1 TO 1.5 METERS TALL

STEP 1: Make the seedbed soil very very wet so the seedlings can be pulled from the ground without damaging the roots.

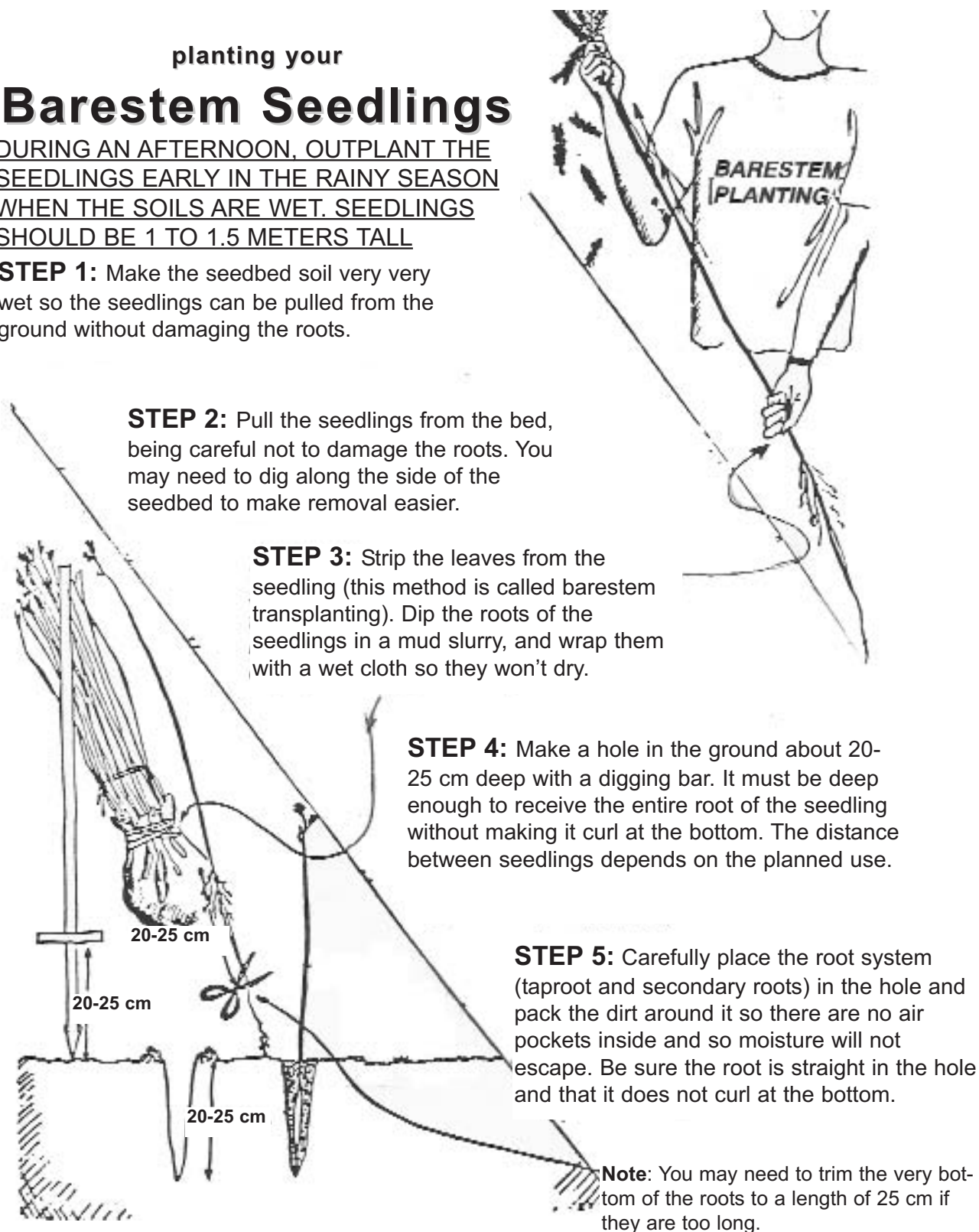
STEP 2: Pull the seedlings from the bed, being careful not to damage the roots. You may need to dig along the side of the seedbed to make removal easier.

STEP 3: Strip the leaves from the seedling (this method is called barestem transplanting). Dip the roots of the seedlings in a mud slurry, and wrap them with a wet cloth so they won't dry.

STEP 4: Make a hole in the ground about 20-25 cm deep with a digging bar. It must be deep enough to receive the entire root of the seedling without making it curl at the bottom. The distance between seedlings depends on the planned use.

STEP 5: Carefully place the root system (taproot and secondary roots) in the hole and pack the dirt around it so there are no air pockets inside and so moisture will not escape. Be sure the root is straight in the hole and that it does not curl at the bottom.

Note: You may need to trim the very bottom of the roots to a length of 25 cm if they are too long.



For more information on nursery production, there is a PowerPoint **Barestem Presentation** on the accompanying CD, as well as a copy of the book *Good Nursery Practices: Practical Guidelines for Community Nurseries* by Kevyn Wightman.

Lesson 11: Vegetative Propagation

Lesson Objective: By the end of this section, YOU will be able to 1) List and explain the reasons for vegetative propagation and give examples of trees that can be successfully propagated this way in your region and 2) List and describe the most common vegetative propagation techniques.

Overview

Trees are most often grown from seed, but some species can be easily and rapidly propagated (reproduced) by techniques such as cutting, layering, division, and grafting, which are all forms of vegetative propagation. When plants are grown from seed, **each one will be different**. However, with vegetative propagation, all of the offspring will be **exactly identical**. This can be very useful, as you will be able to preserve desirable features from the parent plant such as high productivity, superior fruit quality, or high tolerance to stress.

Cutting and Layering

Many shrubs & vines, and some important trees such as Moringa, Jatropha, Gliricidia, Spondias, Pomegranate, and tropical Bamboo, can be easily rooted from stem cuttings. It can help to use a “rooting hormone,” for species that are difficult to root, but for easily rooted species it is not necessary. Typically the best wood to use for cuttings comes from the current seasons’ growth, and is soft enough to bend but hard enough to get damaged when bent more than 2/3. If you can bend it completely without any damage, it is probably too soft.

Make a well-drained, sandy soil mix, and thoroughly water it **BEFORE** you start taking cuttings. To take a stem cutting, cut off about 4-10 inches of a stem (the size can be much larger when making living fences from species such as gliricidia). This piece of stem must have at least 2 nodes (the place on the stem where a leaf or other branch grows from). Leave the top 2-4 sets of leaves, and remove the rest, or significantly reduce them in size by cutting them in half. This helps to protect the cutting from drying out. Gently place the cutting into the soil mix, with at least 1 node 5 - 15 cm below ground. Since the new cuttings do not have roots, they must be kept in the shade, preferably within an area of high humidity, such as a greenhouse, or inside a large plastic bag or tent. It can take from 2-4 weeks (or longer) for the cuttings to grow roots. The plants can be transplanted withing 2-4 months after rooting, though some may need up to a year to fully root.

For plants that are difficult to root, or when you only need to propagate a small number of plants, layering is a good option. With layering, you make the stem grow roots, but **without cutting the stem from the main tree!** This is done in 2 ways. One, called **ground layering** is to bend a branch of the tree to the ground, burying part of the branch 15-20 cm below the soil, while leaving the growing tip above ground. (fig 11A). It can help to put a small rock on top of the buried part of the branch, so that it will remain below ground. The other way, called **air layering**, brings the soil to the tree. To do this, take a fist sized ball of coconut coir (or sphagnum moss) and wrap it around the stem with polythene film (a cut up plastic bag will work well). Make sure the coir is soaked for at least 2 hours before using, and squeeze out the excess water before applying to the tree, as this will help prevent fungal infection. Secure the top and bottom of the polythene with rubber strips from a bicycle tube, or with tape. (fig 11B)

Before layering, it is helpful to wound the stem by making a 2-4 cm vertical cut with a knife. After layering, it can take 1-2 months for roots to form. Once a good number of roots are visible through

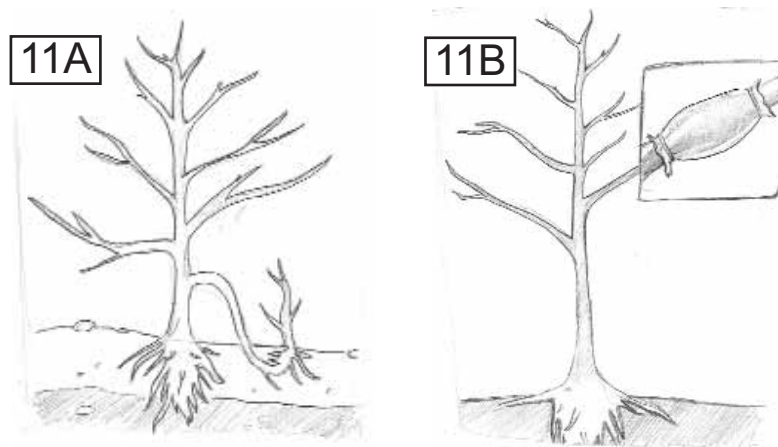


Fig 11: Ground layering (a) and air layering (b)

Lesson 11: Vegetative Propagation

the polythene, you can cut the stem from the rest of the plant. When cut from the plant, the layered cutting will be tender and must be treated with care to keep it from drying out. After 2-4 weeks of “hardening off”, it should be ready for full sun.

Grafting

Grafting is very important for producing high quality fruit. Most fruit trees started from seed will have fruit that is very different, and often of lower quality, from the parent. Grafting produces trees with fruit that is identical to the parent, and is widely used for this purpose. Grafted fruit & nut trees bear fruit faster, sometimes much faster, than seedlings. Grafting requires skill, but with practice, creativity, and a sharp knife, it is possible for anyone to have success without needing expensive equipment.

Grafting is a technique for joining a stem from a tree with high quality fruit onto a seedling of the same species (mango on mango, avocado on avocado) or, sometimes, a closely related species (many of the *Annona* species can be grafted on each other). There are two pieces that are grafted together: the **stock** and the **scion**. The stock is the bottom part (which has the roots), and the scion is the top part (which makes the fruit). **Grafting is the process of joining a scion with a rootstock, so that they grow as one.**

In order for the scion and stock to join, the **CAMBIUM** on the two pieces must line up (fig. 11C). The cambium is the green circle of living tissue that you will see when you cut a stem in half. Try finding it on any stem - it is usually very easy to see. This tissue moves water and nutrients around the plant, and once the cambium from the scion and the stock join, the two will grow as one.

There are many different techniques for grafting, but these different techniques are all just different ways of getting the cambium to line up. The key to grafting is having the cambium line up well, and to keep it from drying out. In order to do this, it is very important to securely bind the scion and the stock together utilizing tightly wrapped plastic. 10cm x 1cm strips of bicycle tubing can be bound around the plastic, to help the stock and the scion make good contact.

Grafting follows the following procedure: **1) Prepare stock 2) Prepare scion 3) Insert scion 4) Align scion properly 5) Bind and seal graft 6) Proper care 7) Success!** The grafted trees must be treated with care, so that the grafts do not dry out until they have solidly healed. They should be kept in the shade, preferably in a high-humidity area. It can take 3-6 weeks for a graft to take. Once the grafted scion is actively growing, remove the plastic and all ties, and allow the plant to slowly adjust to the full sun.

In Senegal mango trees are commonly grafted utilizing the whip and tongue grafting method (fig 11 C-F). In areas with wild fruit trees, older trees can be “top-worked” to new varieties with superior fruits using the cleft graft. You can find more information on various types of grafts in the grafting pdf file on the accompanying CD.

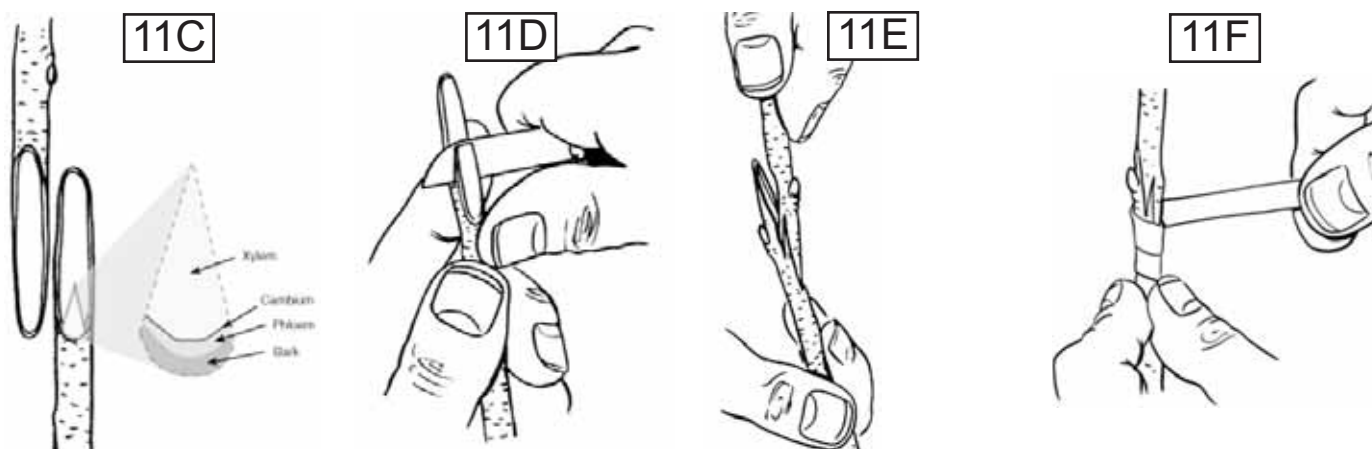


Fig 11: Steps in the whip and tongue grafting method. 11C shows the tissues of a tree that are joined by grafting. from University of Missouri Extension

Lesson 12: Sapling Protection & Dry Season Maintenance

Lesson Objective: By the end of studying Lesson 11, YOU will be able to explain four (4) major ways to protect seedlings in their first dry season.

Each year we receive a number of reports from project leaders telling us that livestock, mostly goats (pic 11A), cattle, and horses, as well as brush fires, destroy many of the seedlings they work so hard to plant. This is especially true in the dry season when forage is generally coarse, dry, and in short supply. It extends into the early part of the rainy season when grass still has not started to grow in sufficient amounts. Through all this time, hungry animals wander about, sometimes pushing through fences, to get at green, succulent forage.

We can readily sympathize: a lot of hard work and a whole planting season lost. Unless planted within an enclosed area, seedlings are most vulnerable to grazing animals during their first dry season. Protection for seedlings can come from weed management and low-cost barriers and deterrents. Here are some ideas on how to increase seedling survival rate while keeping out-of-pocket costs to a minimum.

Protection at the Nursery Stage

We recognize that metal fencing, as sold in most developing countries, is expensive, so we suggest utilizing thorny bushes or dead fences made of thorny branches; anything to protect the seedlings. One can plant a living fence around the nursery area, or, if you are just getting started, collect a bunch of thorny branches and build a dead fence. Placing thorny branches around the perimeter of the nursery - leaving one as a retractable gate - is extremely effective against livestock and wildlife.

We recommend starting trees in a seedbed nursery (see Lesson 10). A seedbed can produce more than 300 seedlings in a square meter by planting seeds 2-3 cm (1-1.5 in.) apart. The compact size of a bareroot bed minimizes water requirements and reduces the length of the required protective fence.



Pic 12B: The firebreak cleared around this field to protect it from brush fires is too small! Firebreaks should be as wide as 20 meters to ensure that brush fires do not destroy your field.

Lesson 12: Sapling Protection & Dry Season Maintenance

Weed/Fire Management

One must also consider weed and fire management (pic 11B). Though weeds can serve as camouflage for seedlings during the dry season, they can also aid in the spread of brush fires that can destroy entire fields very quickly. We recommend eliminating the strongest weeds around each of the seedlings, leaving some brush cover for protection from animals, AND we recommend creating a fire-break around every planting site. The best fire breaks are made by clearing 4 meters of land using rakes, then leaving a space of 12 meters, and then clearing another band 4 meters wide. The 12 meter band of grass in between the two other cleared areas is then control-burned, ultimately leaving a 20 meter wide firebreak!

Protection with Local Materials

There are numerous low cost barriers and deterrents to use. The most important thing is to use local materials creatively. We have seen people use old straw mats, bricks, and even old tires to protect seedlings. Some of the most successful methods are described below.

For new fruit tree plantations, individual trees, which are often spaced 6-12 meters apart, can be covered with rice sacks, onion sacks, or any other similar bag that allows for some sun and air circulation. These plastic mesh sacks can be purchased at most local stores or markets throughout the developing world. They can protect a seedling by fitting them over three large sticks. Just hammer three sticks into the ground around the seedling, and fit the sack on top like a glove. Make sure the sticks are sunk deep into the ground, so that passing cows and goats do not knock them over if they use the tepee to scratch their heads with. Just a few inches of wire to bind the sack to the stakes will hold the sack in place until the next rainy season. Sacks also provide shade from harsh dry season sun and winds, as well as protection from many large insects (grasshoppers, locusts, beetles). The sacks should be checked periodically for damage from sun and animals.

Sticks and thorns can also be used to protect individual trees (pic 11C). If chicken wire or sacks are not available or are too expensive, thorny branches can be woven in between stakes and sticks. Farmers have also claimed success in sprinkling hot pepper, rotten milk, and livestock urine on seedlings to send an instant chemical message to animals; we have not yet tried these methods.

There are also numerous products on the market such as repellents and plastic seedling covers, many of which can be expensive. We recommend trying some of the methods mentioned above; the most important thing is to use local resources creatively. The most crucial step is to help seedlings survive their first dry season. By the end of the second rainy season, trees are usually tall and strong enough that animals can only cause minimal damage. We are always looking for new ideas on seedling protection, please let us know what you are doing!



12C

Can you meet the lesson objective at the top of page 56?

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Glossary- As it Applies to Agroforestry

- A-frame:** Three poles lashed together in the form of an "A", which is used to mark the contours on a hillside for terrace farming.
- Afforestation:** Establishing a forest or forest species on land which has not previously been forested in recent times.
- Agroforestry System:** Is the combination of agriculture and forestry technologies and/or livestock to create more integrated, diverse, productive, profitable, healthy and sustainable land-use systems.
- Alley Cropping:** An agroforestry technique in which trees are planted in rows or alleys within agricultural fields. The trees provide numerous benefits such as soil conservation, organic fertilizers, and water conservation to the agricultural system. Also known as *hedgerow intercropping*.
- Alluvial:** Soil that has been deposited by flowing water.
- Budding:** A common but difficult form of propagation in which the bud of one tree is grafted onto a rootstock to develop into a new tree.
- Canopy:** The cover formed by the leafy upper branches of the trees in a forest.
- Carbon Sequestration:** The removal and storage of carbon from the atmosphere into carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis.
- Compost:** Decomposed organic matter that is produced when bacteria in soil breaks down leaves, rinds and other organic waste, creating an organic fertilizer.
- Conservation:** The preservation and protection of trees and forests for the benefit of the environment and the health of the local people.
- Contour Planting:** The planting of trees along slopes and mountainsides to decrease rain-fed soil erosion and to increase water infiltration and groundwater supplies.
- Coppicing:** A method of encouraging regrowth in certain tree species by cutting the stem close to the ground.
- Cuttings:** An easy and popular form of propagating trees in which the branch of a tree or shrub is planted directly into the ground to develop into a new tree.
- Deforestation:** The loss of forests due to overcutting of trees.
- Endemic:** To belong to a certain region or environment.
- Environmental Services:** It describes the benefits that trees bring to the local and global environment. These services include erosion control, hydrology, carbon sequestration, and supporting plant and animal biodiversity.
- Erosion:** The loss of precious topsoil as a result of wind, moving water or ice, and by such processes as landslides or slow movement of soil over time.
- Exotic:** Commonly used to refer to a plant or other organism introduced from a foreign country or region. For example, *Grevillea robusta*, which comes from Australia, is an exotic tree species in Ethiopia.
- Firebreak:** In agroforestry, an existing barrier, or one constructed before a fire occurs, from which flammable materials have been removed, to prevent fires from damaging fields and homes.
- Fodder:** Leaves, flowers or pods that are used as food by livestock.
- Grafting:** A common method of tree propagation in agroforestry in which a scion from a highly desirable species is fused to the rootstock of another species.
- Green Manure:** A type of cover crop grown primarily to add nutrients and organic matter to the soil. The cover crop is then plowed or mixed into the soil. Green manures usually perform multiple functions including soil improvement and soil protection.
- Indigenous:** A species (e.g. plant or animal) which is native to a given region.
- Invasive:** A non-indigenous species (e.g. plant or animal) that adversely affects the habitats they invade (economically, environmentally or ecologically).

Live fence: A way of establishing a boundary by planting a line of trees and/or shrubs at relatively close spacing and then fixing wires to them, interweaving the lateral branches, or placing bamboo or wood posts to them. Also called a 'living fence'.

Lopping: Cutting all lower and secondary branches to encourage a tree to grow straighter.

MPFG: Refers to multi-purpose, fast-growing trees. These are trees which, in addition to growing quickly, provide numerous environmental services including carbon sequestration, soil regeneration and erosion control. They also provide benefits such as fuel wood, food, fodder, and medicine.

Multipurpose Tree: A tree that is purposefully grown to provide more than one significant contribution to the environment or people's livelihoods. Also called 'agroforestry tree'.

Multistory System: An agroforestry system, such as a homegarden, that has a number of plant species of different size so that several layers of canopy are formed.

Native: A tree which originates naturally from a particular region or environment (same as indigenous)

Nitrogen Fixing: The process by which trees convert nitrogen in the atmosphere into nitrogen compounds in the soil to be consumed by the tree or other plants

Pollarding: Cutting the branches at the top of the tree to prevent the tree from growing beyond a certain height. Similar to coppicing, but higher up off the ground.

Reforestation: Planting trees on lands where trees are depleted or have been recently deforested.

Rootstock: The bottom half of a graft, which provides the roots. It is selected for its adaptability to the local environment, and also at times for having a dwarfing effect to create a semi-dwarf fruit tree.

Scarification: A form of seed pretreatment that nicks the protective seed coat to allow for seed germination.

Scion: The top part of a graft, which is selected for its flowers, fruits, leaves or stems. It is grafted to the rootstock to develop into a new tree that is identical to the tree from which the scion was cut.

Seed Germination: The first stage of growth for a seed, when the protective seed coat breaks down and water enters the seed. This happens only under the right environmental conditions.

Silvopastoral System: Any agroforestry system that include trees or shrubs with pasture and animals.

Sustainable Land Use: Land use that achieves production to meet the needs of present and future populations while conserving or enhancing the land resources on which that production depends.

Slash-and-burn Agriculture: A kind of shifting cultivation in which existing vegetation is cut, stacked and burned to provide some nutrients to the soil and clear fields for future farming; also called 'swidden cultivation' and 'shifting cultivation'.

Wind Break: Usually a long line of tall and short trees and shrubs along a field or garden to block the wind from removing precious topsoil.

Terrace: A broad surface running along the contour. It can be a natural or man-made. They serve the purpose of reducing soil erosion, conserving moisture or to provide adequate soil for plants to grow.

Zero-grazing: A method of raising animals that involves bringing fodder to them rather than letting the animals graze freely. It is commonly done where land is in short supply. Napier grass (*Pennisetum purpureum*) is a common element in zero-grazing systems in East Africa, for example. Trees that can be coppiced, like *Leucaena leucocephala*, provide an important addition to these systems. It is also a function of a silvopastoral system.

Please suggest additional terms that you feel should be included in this glossary



Agroforestry Training Program

Certificate in Agroforestry

Submit the answers to these questions to the address shown on the inside of the back cover. You must score 85% or higher to receive a Certificate in Agroforestry.

Agroforestry Test

- 1) Define and explain sustainable land management.
- 2) Name 3 major sources of brush fires.
- 3) Explain why overgrazing occurs.
- 4) Identify 3 major concerns with planting too many eucalyptus and pine species.
- 5) Explain ways that chemical fertilizers and pesticides damage the soil.
- 6) Explain why atmospheric carbon levels are increasing.
- 7) Define climate change and briefly explain the greenhouse effect.
- 8) List at least 4 environmental problems that have resulted from climate change.
- 9) Explain 3 positive things that trees and forests do to combat the effects of global warming.
- 10) Define agroforestry.
- 11) List 4 keys to success in extending agroforestry.
- 12) Describe the orientation, design, and make-up of a windbreak.
- 13) Describe the design and maintenance of a living fence.
- 14) List the 2 major benefits of alley cropping.
- 15) List 4 major considerations in the design and species composition for alley cropping.
- 16) Explain in two paragraphs how to construct and use an A-frame.
- 17) List the 5 major steps in establishing a contour planting.
- 18) Describe 2 approaches to combating brush/grass fires.
- 19) List at least 4 major characteristics of a forest garden and at least 8 of the 10 zones.
- 20) Describe the economic and ecological values of a forest garden and support your description with examples from your region.
- 21) Identify and explain the agroforestry technologies most appropriate for your region.
- 22) Cite 3 problems with traditional grazing systems.
- 23) List 5 benefits of zero-grazing/cut-and-carry systems.
- 24) Identify 3 forages appropriate for your region.
- 25) Explain the basic principle of fuel efficient stoves and list major steps in making a mudstove.
- 26) Define Integrated Pest Management (IPM) and name at least one IPM technique you can use.
- 27) List the basic ingredients of a compost pile. What should be avoided? Why?
- 28) What 4 non-timber forest products have you identified that your communities can produce?
- 29) Write a description for 2 tree species appropriate to your region that will be helpful in improving local agroforestry systems and explain why these trees are beneficial.
- 30) List 5 of the 7 major guidelines in seed collection.
- 31) Briefly explain important steps in processing seeds.
- 32) List and explain the 5 major factors in seed storage.
- 33) Explain why and how we pretreat seeds.
- 34) When does the rainy season begin in your community (which month)? When should bareroot nurseries be started in your community (which month)?
- 35) List at least four benefits of using barestem seedlings versus plastic polypots.
- 36) List and explain the reasons for vegetative propagation in agroforestry and give some examples of trees that can be successfully propagated this way in your region.
- 37) Explain 4 major ways to protect seedlings in their first dry season.
- 38) What questions do you still have about agroforestry?

Despite the existence of easy-to-implement agroforestry techniques that can solve most of the major agricultural and land use problems, communities throughout the world continue to suffer from desertification, drought, flooding, erosion, and frighteningly low agricultural production. There exist plenty of improved land use systems that maximize production while improving soil quality and conserving natural resources, **but** this vital information is not getting to the people who need it most! Since 1988, Trees for the Future has helped communities to plant over 50 million trees, reforesting tens of thousands of acres, and bringing sustainable income and food security to thousands of communities. This packet is intended to give YOU the agroforestry knowledge to take this life-giving program to the people who need it most.

The Goal of This Training Packet:

During the next year, YOU will implement reforestation and/or agroforestry activities, demonstrating an application of the principles, solutions, and alternatives presented in this training packet. Each of the lessons in this training packet begins with specific objectives. At the end of each lesson, you will be expected to be able to meet those objectives. The final evaluation of this long distance training course is the the submission of your answers to the agroforestry test at the end of this packet. Submit your answers to:

Distance Training
Trees for the Future
PO Box 7027
Silver Spring, MD 20907
USA
or email them to:
training@treesff.org

Upon successful completion of this training packet and submission of your agroforestry test, all participants scoring 85% or higher will be awarded an **Agroforestry Certificate** by **Trees for the Future, Inc.**, and you will become eligible for material support and a **Deppner Conservation Award**.



Additionally, you will be able to deliver this training program, or an improved version of this training program, to communities in your area. This packet can also be used as a training lesson plan.

YOU are becoming a critical part of this people-to-people action program that trains communities to reforest degraded lands while conserving the environment, creating income generating activities, and improving the quality of life. Thank you.

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Trees can help build terraces that prevent erosion and mudslides

Trees give a continuing supply of poles and posts for construction and other needs.

Trees produce organic fertilizer that will improve the soil quality and increase crop yields.

Trees can create living fences that serve as a multi-purpose barrier to wind and animals.

Trees can produce a continuing supply of firewood for use and sale.

Tree leaves and seed pods can be used as high-protein forage for livestock, fish, and poultry.

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