CHIKUNI PARSH TAONGA AGRO-FORESTRY PROGRAMME

CONTENT GUIDE
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Notes about this guide:

This guide was produced for the purpose of compiling and organizing the information and techniques from Taonga Agro-Forestry Programme developed by Bornface Hangala at Chikuni Parish. This guide is meant to aid with the future development of a full agro-forestry curriculum by providing a comprehensive list of important topics and methods that can be formed into lessons. The guide can also serve as useful resource for mentors and students who may need additional information about the concepts presented by the future curriculum.

Although this guide was created specifically for the Chikuni Parish Taonga programme, the concepts within can, and should, be shared with other organizations looking to implement similar programs in other areas. The guide is intended to be a compilation of techniques and theory that can be used in a variety of situations in many different countries and by no means should be restricted to the Chikuni area. Sharing of the content is highly encouraged especially to organizations similar to Chikuni Parish Taonga.

The guide is divided into two parts. Part One aims to introduce students and mentors to the general ideas, concepts, processes, and components of the natural world. Students should gain a basic understanding of these as well as an understanding of how humans impact the environment. These concepts should be accompanied by small demonstrations and experiments when appropriate. Part One also aims to build a foundation that will make understanding the importance of agro-forestry easier for the students.

Part Two explains the main components of the agro-forestry Programme. This part deals more with methods and specifics rather than concepts and themes. As mentioned before, Part Two builds on and refers to the concepts from Part One and offers a practical explanation of how these concepts can be worked into the agricultural practices of smallholder farmers in rural Africa. Because every agro-forestry garden is different, this guide can only cover the general methods. Therefore, additional information should be sought from the agro-forestry technician regarding any specifics.

Many concepts overlap and are interrelated and therefore it is important that the chapters are not treated as individual items. Many chapters refer to material from other chapters and it is important to refer to topics covered in the past when they come up again.

At the end of each chapter there is a list of Key vocabulary words. Some of these words are written in **bold** in the text so they can be referenced. These are the essential concepts covered in each chapter and are useful terms that can be used for testing or homework.

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PART TWO: AGRO-FORESTRY

PART ONE: ENVIRONMENTAL SCIENCE

CHAPTER 1: Creating a Sustainable Environment

The Environment

What is the environment? The **environment** is a term used to explain the natural world and all of its components, processes, and functions. The environment includes both living and non-living things. Plants, animals, insects, water, soil, rocks, air, and even humans are all part of the environment. All of these components are related and connected in some way. The environment depends on a delicate balance between these many components and disturbing any one of them can cause the others to be damaged.

As mentioned before, humans are an important part of the environment. The water we drink, the air we breathe, the food we eat, and materials we use to build our houses all come from the environment. We depend entirely on the environment for our survival and without it, we would be unable to live and prosper.

Resources and the environment

The things that we take from the environment for our use are called resources. **Resources** include plants, animals, water, fuel and many other things. Again, all humans depend on resources to survive and prosper.

One of the most important resources is the **land** itself. Many other resources depend on land such as trees and animals. The land provides us with soil to grow our crops in, rocks and dirt to build bricks out of, and space to raise our animals and construct buildings. The land also has many resources buried underneath it. Deep in the Earth there are many minerals and metals, which we use to make things like steel, copper, and glass. There are also

resources like coal and oil, which are used for fuel. We gather these resources by **mining** deep under ground.

Plants are another important resource. Plants provide us and other animals with food to eat. Plants produce fruits, vegetables, nuts, and seeds. Plants also provide us with other materials like cotton for clothes, and are used for making other products like paper. We also use plants to build our houses. We use the wood, or **timber**, from trees as well as grass for our roofs and fences.

Another very important resource is **water**. All animals, including humans, need water to survive. Our bodies are made up of mostly water and we cannot live for very long without drinking water. Plants also rely on water for survival and therefore we need to have water for our crops. The fish that we eat live in water and rely on clean water to survive. We also use water to keep things clean so that we can stay healthy.

Animals are another resource that we depend on to survive. We use **Livestock**, such as goats, cattle, pigs, and chickens, for food, milk, and eggs. We also use animals such as horses, mules, and oxen to pull our ploughs and carts. We take the hides of cattle to make leather and the wool of sheep and goats to make fabrics.

Another resource that we rely on is **fuel**. Fuel is used for powering machines, lighting homes, cooking, and heating. Some fuel comes from trees that we burn as firewood or make into charcoal. Other fuel must be mined from the ground, such as coal. Kerosene, paraffin, and petroleum also come from the ground in the form of oil and are used as fuel for lamps or to power automobiles.

There are many other resources that humans take from the natural world besides the ones mentioned here. But it is important to remember, however, that all resources come from the environment.

Sustainable use of resources

As mentioned before, humans are part of the natural world and we play a large role in shaping the environment. In today's world, we have the ability to significantly alter the world around us. Sometimes, however, our actions can harm the environment and threaten our own survival.

Even though we need resources to survive, if we are not responsible about how we use these resources, we can damage the environment. Because all resources come from the environment, it is critical that we protect the environment so that we can continue to live. Unfortunately, the world population is growing very rapidly. This rapid **population growth** has led to an increased demand for resources. More people on earth means a higher demand for resources to give us food, shelter, and other materials.

The environment is a delicate system and we have to be very careful in how we treat it. Activities such as mining, raising livestock, and logging forests for timber and charcoal if not done responsibly can severely harm the environment. Therefore, we must make sure that we use resources sustainably.

Sustainability means using resources to meet the current needs of humans, while ensuring that there are enough resources to meet our future needs. If we do not use our resources sustainably, then we will not have enough resources to survive in the future. For example, if we cut down all of the forests we will have no timber for buildings, firewood, or charcoal. Similarly, without clean water we will not have anything to drink or any crops to eat.

The sustainable management of resources can help protect the environment in many ways. But sustainability can also improve our health and even increase our income. There are many ways in which a person can practice sustainability, but this guide will primarily focus on agro-forestry.

Key Vocabulary:

- Environment
- Resources
- Mining
- Timber
- Livestock
- Fuel
- Population growth
- Sustainability

2: Keeping the Environment Clean

The sustainable use of resources is essential for protecting the environment. In addition to practicing sustainability, however, we should ensure that we keep the environment clean and healthy so that it functions properly and continues to provide us with the many resources that we need.

Pollution

One way to avoid damaging the environment is to keep it clean by preventing pollution. **Pollution** is when contaminants that have harmful effects are introduced to the environment. Pollution can cause resources like water and land to become toxic and unusable. Pollution can also change how environmental systems function, which can cause the environment to become unbalanced.

Pollution can affect many different components of the environment. The major types of pollution are land pollution, water pollution, and air pollution. Pollution can be cause by waste, chemicals, sewage, fumes, and small particulates like soot or dust.

Land Pollution:

Land pollution is generally associated with **waste** or **litter** that is improperly disposed of. Plastic bags, bottles, cans, paper products, old/broken electronics, and other rubbish, which are not disposed of properly, end up polluting the land. Because these items do not break down or decompose, they end up contaminating the land. Putting chemicals on the land for farming or other purposes also pollutes the land

Water Pollution:

Water pollution involves any contaminants that enter the water system making it unsuitable for drinking and poisonous for plants and animals. One common form of water pollution is **sewage** from toilets. Water can also be polluted from things like laundry water, which has soaps and detergents in it. Dumping rubbish or litter into the water can also contaminate it. Many industries and mining companies, which produce a lot of toxic by-products, contribute to severe water pollution.

Air Pollution:

Air pollution occurs when fumes, gasses, or particulate matter contaminate the air. Air pollution generally comes from the burning of things such as petrol, kerosene, charcoal, and firewood. When these resources are burned in the engines of machines or in the household, they release fumes and gases into the air, which can poison the air or change its composition. Air pollution can also come from dust and small particles of ash or soot that are stirred up and taken into the air.

Negative impacts of pollution

Pollution can have many negative impacts on the environment, our ability to use resources, and even our health. When we don't dispose of rubbish and litter, some animals will eat the waste and become ill or die. Similarly, when the land is covered in waste many plants cannot grow as well as they would otherwise. When chemicals are dumped on the land, the soil can become contaminated and it will no longer support plants.

When the water becomes polluted with sewage or chemicals from wastewater, it can cause many problems. Polluted water cannot be used for drinking, cooking, or cleaning. Contaminated water can cause rashes or diseases like Cholera and many diarrheal illnesses, which may lead to death. Polluted water also poisons or kills fish and other aquatic animals. When animals such as birds or humans eat poisoned fish, the poison is passed on causing illness or death. Water pollution will be discussed further in *Chapter 3.*

Air pollution can cause a variety of major problems. When we breathe in polluted air, we can damage our health. Some of the fumes created from burning charcoal and kerosene are poisonous for us to inhale. Similarly, when we breathe in air that has a lot of dust or soot in it then we can damage our respiratory system. Breathing in polluted air can cause us to cough, and sneeze and can result in lung diseases such as asthma, bronchitis, and cancer. Air pollution can also have many impacts on the environment. For example, polluted air can contaminate the rain, causing it to be acidic or poisonous. This is called **acid rain**, which can kill trees, crops and other plants when it falls. Air pollution will be discussed further in *Chapter 4.*

Preventing pollution

If we do not prevent pollution, we can damage, poison, or kill many of resources that we depend on. Preventing pollution can help us to maintain a clean environment that functions properly. When we take measures to prevent pollution, we are practicing sustainability because we are making sure that we do not destroy the resources that we will need in the future. Even though there are many forms of pollution and many negative effects caused by pollution, there are also many ways to prevent it.

THE THREE R'S:

One of the main ways to prevent pollution is to practice the **Three R's**. The Three R's stand for Reduce, Reuse, and Recycle. The first R, **Reduce**, refers to the idea that we should reduce the amount of waste that we produce. This means that when we have litter or rubbish, we should dispose of it in litterbins, rather than throwing it on the ground, so that it can be disposed of properly. We can also reduce the amount of waste by not buying products with lots of packaging.

The second R, **Reuse**, refers to the idea that we should reuse things whenever we can. When we buy food that comes in a plastic sack, instead of throwing the sack away, we should keep the sack and use it again the next time we go to buy food. Plastic Coke bottles can be reused by refilling them with water or other beverages over and over again. Once we use something, we should look for other ways in which we can use the item again so that we don't need to buy new things and create more waste. Reusing items can also save money.

The third R, **Recycle**, is very important for reducing pollution and conserving resources. Recycling is the process of converting waste material into new items. Many products and packaging made from plastic, paper, or glass, can be recycled and turned into new products. Paper, for example, which has been written or printed on, can be recycled and turned into new fresh paper. Many recycled items require recycling plants and must be placed in recycling bins in order to be taken to these facilities. But we can also recycle items without sending them to a plant. For example, old tyres can be reused as building material.

OTHER METHODS FOR PREVENTING POLLUTION

Aside from the three R's there are many other ways to prevent pollution. First of all, making sure that we dispose of our rubbish in litterbins is important for keeping the land from becoming polluted. There are many products that are biodegradable. **Biodegradable products** are products that naturally decompose and break down when they are put into the environment. Unlike plastics and glass, biodegradable products will break down and become part of the earth without polluting the land. It is important to try and buy biodegradable products whenever possible.

We can also prevent pollution by making sure that our sewage is contained and that it does not find its way into our water systems. Making sure that we do not pour chemicals or toxic waste into the water is also important for keeping the water clean.

Because burning kerosene, charcoal, and firewood can pollute the air, investing in solar lights or cleaner stoves can reduce this because they do not produce fumes, which pollute. Even without these products, however, we can ensure that we try to use as little firewood and charcoal as possible so that we can minimize the fumes that we produce. Planting trees is also an important way to fight air pollution, because trees and other plants help to clean the air and remove pollution, a topic that will be covered in *Chapter 5* and *Chapter 7*.

We must make sure that we do not carelessly pollute the environment so that we can protect our resources and ourselves. It is important to pay attention to how we dispose of our waste and to try and reduce, reuse, and recycle whenever possible. Preventing pollution can help protect the environment, keep us healthy, and even save us money.

Key Vocabulary:

- Pollution
- Land pollution
- Water pollution
- Air Pollution
- Chemical Pollution
- Recycling
- Biodegradable products

CHAPTER 3: Water

As mentioned in *Chapter 1*, water is one of our most precious resources. Without water, we would not be able to survive. All animals including humans need to drink water to live. Plants also require water and without enough water, we cannot grow crops or food. Fish and other aquatic animals require clean water in order to survive and stay healthy because they live in the water itself. We also use water for cleaning and cooking. Water is perhaps the most important resource that humans need to live and it is critical that we manage water responsibly.

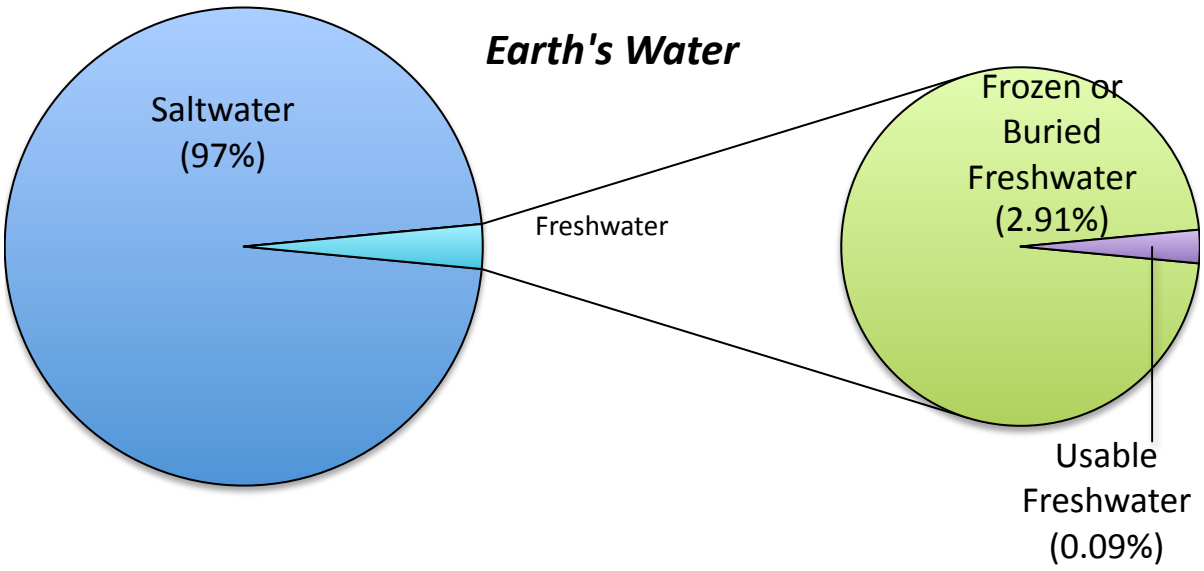
Where does water come from?

In order to protect our water resources, we must understand where water comes from. The amount of water on earth has always been the same. There is no way to create water or destroy water. Water does, however, have different states. The water we drink and use to water our crops is called **liquid water**, which accounts for most of the water that we see.

When water gets very cold (below 0° C), it freezes, turning into solid **ice**. Ice is found in very cold places like the North and South Poles. When water gets very hot, it turns into **water vapour**. Water vapour is a gas and it is invisible. Even though we cannot see it, the air is full of water vapour. Water vapour is what helps to form the clouds that we see in the sky.

Over 75% of the earth's surface is covered in water. This means that there is three times more water than there is land on earth. Although there is a lot of water, the majority of this water is found in the oceans. In fact, about 97% of the all the water on earth is saltwater. This water is called **saltwater** and even though many marine animals live in saltwater, it is poisonous for humans and plants. This means that we cannot drink it or use it to water our plants.

The rest of the water on earth is called **freshwater** and it accounts for 3% of the total water. Of this freshwater, however, about 97% of it is frozen as ice in very cold regions, or buried deep beneath the ground. This means that of all the water on earth, less than 0.1% of it is available for use. In other words, water is a very scarce resource. The chart below illustrates how the earth's water is divided.



The freshwater that is available to us can be found in several places. Freshwater can be found in rivers like the Zambezi River or in lakes like Lake Kariba. All of the rain that falls is made of freshwater that can be collected. A lot of freshwater can be found deep underground and is called **groundwater**. Groundwater can be collected by digging deep wells or drilling boreholes that can be used to pump up this clean water from deep below the earth's surface.

The water cycle

All of the water on earth is involved in a constant cycle called the water cycle. The **water cycle** is the process by which water changes states and is moved around the earth. It is one of the most important environmental processes and without it we would have no rivers, lakes, or rain.

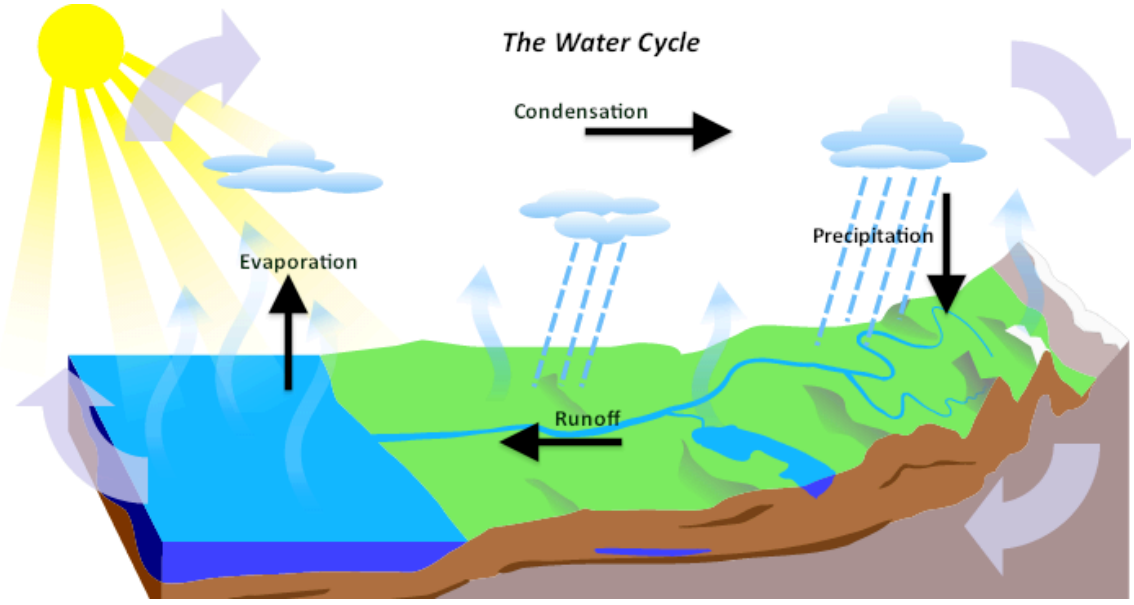
When we see the rain fall, we are witnessing one step in the water cycle. Rain is one form of precipitation. **Precipitation** is a term used to describe the water that falls from the sky. Precipitation can come in the form of liquid rain or frozen snow and hail. Snow and hail only occur in very cold regions of the earth where the precipitation freezes before it falls. Here in Zambia, we experience precipitation in the form of rain.

When the rain falls to the ground, different things can happen to it. Some rainwater is absorbed into the ground and seeps down to become groundwater. Other rainwater forms runoff. **Runoff** is when rainwater hits the surface, collects, and then drains into streams and rivers. These rivers and

streams then eventually form lakes or flow into the oceans. Every time we see a rushing river, we are seeing runoff.

The next step of the water cycle occurs when the sun heats water on the surface of oceans, lakes, or the ground. When liquid water is heated by the sun, it is turned into water vapour by a process is called **evaporation**. When water evaporates, it is turned from a liquid into water vapour and then taken up into the air. If you were to leave a cup of water out in the sun for a few days, eventually, all of the water inside would evaporate and turn into water vapour. As mentioned before, much of the air we breathe is made up of water vapour.

The next stage of the water cycle is called condensation. **Condensation** is when water vapour is cooled down and turns back into liquid. Every time we see a cloud in the sky, we are seeing condensation. Very high up in the air, the temperature is much colder and the water vapour cools enough to turn back into liquid drops which form the clouds we see. Eventually, these clouds become so full of water that the droplets are heavy enough to fall back down to earth as precipitation, or rain. When rain begins to fall from the sky, we are seeing the whole water cycle starting over again.



Managing water resources

As we now know, freshwater is a very limited resource. Even though there is a lot of water on earth, only a small amount of it can be used by humans. We also know that water is constantly going through the water cycle,

turning from rain into rivers, then water vapour and clouds, and finally back into rain. Knowing these facts about water can help us to understand how we can protect this important and delicate resource. Firstly, we must understand that water cannot be wasted. This is called **water conservation**, and it describes the process of protecting water and preventing it from being wasted.

Water conservation has two main components. Firstly, it is important that we protect the water that we have. As discussed in *Chapter 2*, water can be polluted when litter, sewage, and chemicals are put into it. When water becomes polluted, it can become unusable. We cannot drink polluted water, fish cannot live in it, and plants cannot survive with it. Because there is so little water on earth, we cannot afford to pollute any water. If polluted water evaporates and is turned into clouds, the rain that is produced will also be polluted. This is called **acid rain**, and it can cause entire forests and fields of crops to become poisoned and die when it falls.

Mining, like that done in the Copperbelt, can also cause serious water pollution. When mining companies tear up the ground to access the mineral resources below, they uncover many toxic metals that can be washed into rivers and streams, causing the water to become polluted.

Conservation also involves preventing water from being wasted. When we are gathering water from a pump, it is important not to let the water go to waste. All the water that we take should be used for watering crops, drinking, cooking or washing. Wasting water is dangerous because there is so little water on earth. We can also prevent ourselves from wasting water by making sure that we don't use too much when we are watering our crops. Conserving water while farming will be discussed further in *Chapter 16*.

Key Vocabulary:

- Liquid water
- Ice
- Water vapour
- Saltwater
- Freshwater
- Groundwater
- Precipitation
- Runoff
- Evaporation
- Condensation
- Conservation
- Acid rain

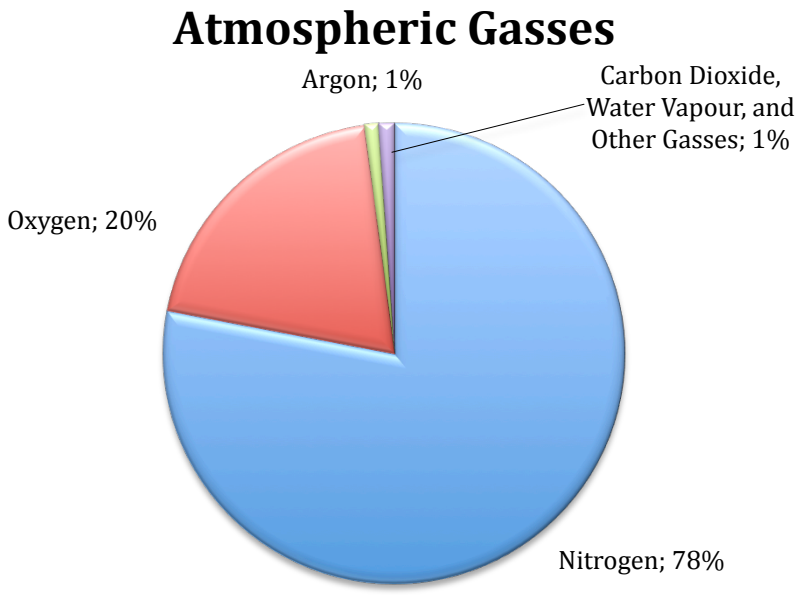
CHAPTER 4: Air

All living things on earth require air to survive. Humans, animals, insects, plants, and marine organisms need air to live. Animals, like humans, take in air every time we breathe. Plants take in air through their leaves and fish take in air that is dissolved in water through their gills. Air is vital to many environmental systems and in order for these systems to function properly the air and its components must remain clean and balanced.

The atmosphere

Even though the air is invisible, it is very complex. There are many different types of air which are knows as **gasses**. Each gas has different properties. Some gasses are essential for life and other gasses are poisonous to breathe in.

The air that we breathe in is all part of what is called the atmosphere. The **atmosphere** surrounds the entire earth and is made up of many different gasses. These gasses are mixed together in the atmosphere and are spread across the entire globe. There are many different gases but the atmosphere is consists mainly of 5 major gasses. These gasses are nitrogen, oxygen, argon, carbon dioxide, and water vapour.



As we can see from the chart above, the most common gas in the atmosphere is **nitrogen**. Nitrogen is essential for life on earth, but only when it is converted into another form than that is found in the atmosphere. This concept will be discussed further in Chapter 13.

The next most abundant gas in the atmosphere is **oxygen**. Oxygen is also essential for life on earth. When we breathe in, we inhale all of the gasses in that are floating around in the air. Oxygen, however, is the most important and is the one we need to survive. When we breathe in, oxygen in absorbed through our lungs into our blood. It is then pumped throughout our entire body. Without enough oxygen, our bodies would be unable to function. When we breathe in we take in oxygen, but when we breathe out, we expel carbon dioxide, the next most important gas in the atmosphere.

Carbon dioxide although, not very abundant, is one of the most important gasses in the atmosphere. While humans breathe in oxygen and breathe out carbon dioxide, plants do the opposite. Plants take in carbon dioxide and release oxygen through their leaves. Plants use carbon dioxide to help them grow by taking the carbon and turning it into plant material. This will be discussed further in *Chapter 5* and *Chapter 7*. Carbon dioxide also has many special properties that help to regulate the earth's atmosphere.

The other major gas in the atmosphere, Argon, has no important properties and is what we call an inert gas. Argon is not essential for life despite being the third most prevalent gas. As discussed in *Chapter 3* water vapour, another common gas, is important for the water cycle because it helps to produce clouds and rain.

What does the atmosphere do?

Even though air is essential for breathing and living organisms, the atmosphere has several other functions that help protect the environment and all living things. The atmosphere extends about 800 kilometres into space and is made up of many different layers. Despite the fact that the atmosphere is very large, it must be maintained in order for it to continue to provide the services that it does.

One of the most important functions of the atmosphere is to keep out harmful rays from the sun. The sun is a very powerful object and even though it is very far away (almost 150 million kilometres!), the energy it produces can still harm us on earth. While the sun produces light and heat, it also produces

invisible rays called **ultraviolet (UV) rays**. These rays are beneficial to humans in small amounts, but if we get too much exposure to them, they can cause health problems like cancer. The atmosphere and the gasses within it, help to absorb and reflect some of these ultraviolet rays and protect us from their harmful effects. When we pollute the air with chemicals, we can damage the atmosphere and damage its ability to protect us from these harmful rays.

The other major function that the atmosphere provides is temperature regulation. As mentioned before, the sun is what provides earth's heat. When the sun is up during the day, the temperature is much warmer than it is at night when the sun is down. Without the atmosphere, however, the heat that comes from the sun would escape into space, causing everything on earth to freeze completely and die. Some gasses in the atmosphere are important for trapping the heat that comes from the sun and preventing it from escaping into space, thus keeping the earth warm, even at night. These gasses are called **greenhouse gasses** and without them, nothing could live on earth.

Climate change and global warming

One of the most important and abundant greenhouse gasses is carbon dioxide. As we know, carbon dioxide is important for life but it is also a greenhouse gas, which keeps earth's temperature stable. Carbon dioxide is created not only when animals breathe out, but also when we burn fossil fuels. **Fossil fuels** are fuels such as firewood, charcoal, kerosene, paraffin, diesel, and petroleum. Every time we light a fire, cook with charcoal, or drive a car, we are burning these fossil fuels and when we do, we are creating carbon dioxide and releasing it into the atmosphere.

As mentioned before, the atmosphere is delicately balanced, and changing any of its components can have many effects on the environment. Therefore, if we create too much carbon dioxide, we will change the composition of the atmosphere. In other words, putting too much carbon dioxide into the atmosphere is another form of pollution. Because carbon dioxide is a greenhouse gas and traps heat, the more that we put into the atmosphere, the more heat it will trap.

Over the past few centuries, humans have been burning more and more fossil fuels, and putting more and more carbon dioxide into the atmosphere. This has resulted in a phenomenon called global warming. **Global warming** is the process by which increased amounts of greenhouse gasses, primarily

carbon dioxide, cause more of the sun's heat to be trapped, which in turn causes the earth's temperature to increase. This is a very serious environmental concern for many reasons. If the earth's temperature gets too high we will see more things such as droughts and bushfires, which can destroy crops and kill livestock.

Increasing temperatures will also result in the melting of ice at the North and South Poles. Not only will this water flow into the ocean and become saltwater, which we know cannot be used by humans, but it will also cause the oceans to rise. This is a problem for coastal countries and cities, which may become flooded. As these floods occur, people will have to flee their homes and seek refuge in inland places like Zambia, putting further pressure on the environment.

Global warming is a major threat to the environment on a global scale. But it is only one component of a larger problem known as climate change. **Climate change** is a process by which the world will see more extreme climate events such as floods, droughts, and cyclones or hurricanes. Climate change can also cause things such as the temperature to have larger changes. In recent years, parts of Zambia have experienced hotter summers and colder winters, which can kill crops and cause many other problems.

Climate change is one of the most serious problems facing our world today. While air pollution through the burning of fossil fuels is a major cause of climate change, it is not the only one. The concept of climate change is very complex and will be explored several more times in this guide. Preventing climate change will be essential for humans in the future and if it is not addressed, development will be unlikely to occur in places like Zambia.

Key Vocabulary:

- Gasses
- Atmosphere
- Nitrogen
- Oxygen
- Carbon dioxide
- Ultraviolet rays
- Greenhouse gasses
- Fossil fuels
- Global warming
- Climate change

CHAPTER 5: Introduction to Plants

Aside from pollution, one of the most important methods for preserving the environment is to protect plants and trees. As we know from *Chapter 1*, plants are one of the most valuable resources on earth. They provide us with timber, food, fruits, nuts, and firewood. They are also used to make things like cloth and paper.

We also know from *Chapter 4* that plants are essential for creating oxygen that all animals need to survive as well as removing carbon dioxide. Without plants and trees, there would be no oxygen for us to breath and we would die. Plants and trees are also hugely important for taking carbon dioxide, the greenhouse gas discussed in the previous chapter, from the atmosphere. In other words, plants help to regulate the atmosphere and clean it from the fumes that we put into it every time we cook with firewood or charcoal, or drive a car.

Understanding how plants are structured, what they need to survive, and how they grow, is central to the concept of agro-forestry. Understanding why plants are important and how they work can also help us to grow better food, make more money, be healthier, and protect the environment from climate change and other problems.

Basic plant structure and components

There are thousands of plant species on earth, each one with different characteristics and properties. Some plants, like trees, grow very large and strong, while others, like grass, are smaller and are less rigid. Still other plants, like algae, which grow in water, are tiny and hard to see except in large quantities. Nevertheless, most plants have some similar components and require the same things for survival.

Most land plants have five major parts: stems, leaves, roots, seeds, and flowers. Each of these components serves a different function and can be used by humans for different things.

The first important part of any plant is the stem. The **stem** is essentially the main body of the plant that rises out of the ground. The stem provides structure for the plant and keeps it from breaking or falling over. Some plants, like trees, have very thick stems that are very hard and strong. These are also

called trunks, and they are often covered in hard bark. Tree trunks are where we get wood for firewood, charcoal, and building material. Other plants, such as grass, have smaller stems that are less rigid and do not have any bark on them. Most stems grow up from the ground and then branch out from the main stem forming smaller stems called **branches**.

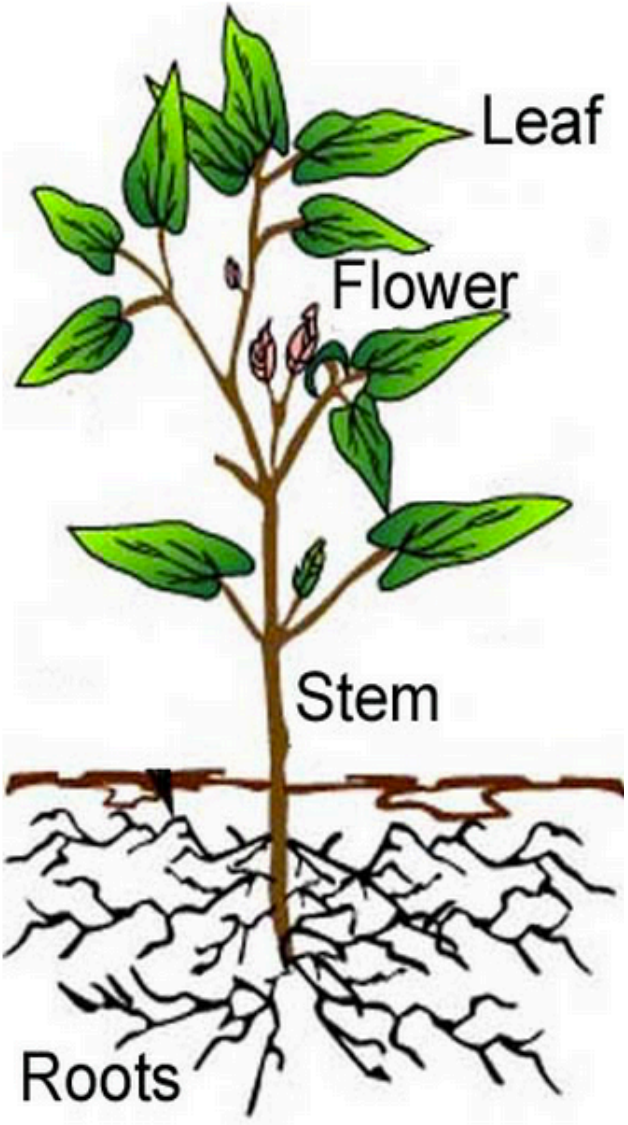
Growing from the end of the branches and stems is another very important part of any plant, the leaves. Leaves come in many shapes and sizes and no two plants have the same leaf shape. **Leaves** are where plants get their energy from the sun, where they expel water, and where they take in and release gas. As we know from *Chapter 4*, leaves are where plants take in carbon dioxide and also where they release oxygen into the air. Most plants lose their leaves in the winter when the temperature gets cold and grow new ones in the summer.

While stems and leaves are very important, plants do not only grow above ground. Below the earth, plants grow large networks of roots. **Roots** can grow many meters under the ground and are important for bringing nutrients to the plant as well as anchoring it in the soil. Roots grow deep into the ground so that they can take up groundwater to feed the plant. The roots also bring many essential nutrients that are in the soil up into the stem and leaves of the plant. Some plants have roots that grow very large and fleshy, such as carrots, turnips, and potatoes, which we eat as food.

Most plants produce **seeds**, which grow into new plants when planted in the ground and cared for. In order to grow any crops for a farm, we must first have access to seeds. Many of the foods that we eat directly or turn into other foods are seeds, such as maize, wheat, and nuts. Seeds can form in many different places on the plant. Some seeds are formed in pods, such as pigeon peas, which sprout from the stems, or groundnuts, which are formed underground.

Seeds can also be found in the flower of a plant. **Flowers** are vital to the reproduction of plants. Many flowers produce **pollen**, which fertilizes the seeds of other plants and is carried between flowers by the wind or by bees and other animals. Seeds can also be found in the fruit of plants. **Fruits** like bananas, mangoes, and guava, all have seeds within them.

Structure of a plant



Plant needs and processes

Plants have many requirements in order for them to survive. Some of these needs we have already discussed in previous chapters. For example, we know from *Chapter 3* that plants need water to survive. Water is used to keep plants from drying out and is necessary for many of the functions that occur within the plant. Plants grow deep root networks, which draw up water from the ground and bring it up into the plant. The water moves up through the entire plant all the way to the ends of the branches and into the leaves. When water reaches the leaves, it is given off into the atmosphere through small pores in the leaves as water vapour in a process called **transpiration**. As water leaves the plant and evaporates into the atmosphere, new water is drawn up from the ground and the process starts over again.

We also know from *Chapter 4* that plants require air to survive. On the leaves of plants are tiny pores, which allow gasses like carbon dioxide, oxygen, and water vapour to pass. We know that plants take in carbon dioxide and turn it into new plant material, finally expelling oxygen.

In order to turn carbon dioxide into new plant material, plants require energy. Animals, like humans, get our energy from the food we eat, which we convert into sugars, which power our bodies and minds. Plants get their energy from a very different source, the sun. This is a process called **photosynthesis**, whereby plants take the energy from sunlight to convert carbon dioxide into new plant material. The energy from the sunlight allows plants to grow new leaves, roots, and stems from the carbon dioxide that they take in through their leaves. When this process is over, the carbon dioxide has been converted into plant material and all that is left is oxygen, which is expelled back into the atmosphere. Generally, photosynthesis occurs in the leaves of plants. When we see green leaves, we know that photosynthesis is occurring. When the leaves are brown and dry, like in the winter, photosynthesis is not occurring.

Plants also require good soil to grow in. Soil not only provides the material that roots grow in to anchor the plant, it also provides the nutrients that plants need to grow. Soil that is full of nutrients is known as **fertile soil**. Fertile soil is necessary for growing crops and is central to the concept of agro-forestry. When plants have fertile soil to grow in, they will grow faster, larger, and produce more fruit. Like water, the nutrients in the soil are taken up into the plant by the roots. Soil fertility will be discussed further in *Chapter 6* and *Chapter 13.*

Plants also require the right temperature. When the temperature gets too cold, plants will freeze and can sometimes die. When frosts occur, many crops will die off or become damaged. If the temperature becomes too hot, however, plants can dry up or even burn. Therefore, large temperature swings like those being cause by climate change (*Chapter 4*) are a threat to many plants.

Plant lifecycle

In order to understand agro-forestry, we must understand how plants grow. Now that we know the structures of plants and their many processes, we can start to look briefly at the plant lifecycle.

As we know, new plants come from seeds. Some seeds are spread by the wind or by animals. Other seeds simply drop to the ground underneath the plant. Seeds that fall on fertile soil and have enough water and sunlight will eventually begin to sprout. The tiny plant called a **sprout** will grow up out of the soil reaching for the sunlight. It will also start to grow some roots to bring in nutrients and water. These sprouts often only have one stem and a few tiny leaves.

Eventually, the sprout will grow larger and become a seedling. **Seedlings** are larger than sprouts but are still not fully grown. Often, seedlings are eaten by animals or burnt by bushfires. When growing crops, it is important to make sure that they are protected from these threats. Seedlings that are healthy will eventually grow into large mature plants that then produce their own seeds and start the process over again. The benefit of seedlings is that they can be dug up and replanted in a different place. This will be discussed further in *Chapter 15*.

When we cut down plants or they are burned in bushfires, some will die. Others, however, have the ability to **re-sprout**. When a plant re-sprouts, new stems grow from the stump of the old plant or out from the roots. This means that the plant does not need a seed to re-grow. The new sprout, if protected from animals and fire, will eventually grow up to be a mature plant again.

The benefits of plants

We already know that plants are an incredibly valuable resource for humans. We eat the fruit, seeds, and roots of many plants. When bees visit the flowers of plants, they take sweet nectar from the bottom of the flower, which they use to make into honey. We also get building material like wood and grass from plants. Fuel like charcoal and firewood comes from plants. Even coal, another fuel source dug up from deep underneath the ground, is just old plant material that has turned to rock. We also know that we use plants for cloth and paper as well. Plants have also been responsible for many medical breakthroughs. Most of the ingredients for the medicines that we use today to fight diseases were discovered in plants. There are many plants that exist that have not been studied fully and they may hold the key to solving some of the world's worst sicknesses.

Aside from the resources that we get from plants, there is also a set of services that plants provide which help to keep the environment healthy. We already know that plants are essential for keeping the atmosphere clean. They not only remove carbon dioxide, a greenhouse gas, but they provide us with the oxygen that we need to breathe in order to survive.

The roots of plants are also very important for keeping soil in place. Wind and water can carry away fertile soil and leave us with no place to grow crops. The roots of plants help to prevent this from occurring and keep the soil stable.

Large plants like trees are also useful for slowing the wind and keeping temperatures regulated. Forests can help to block the wind that can carry away soil or damage our houses. Forests also help to keep temperatures from getting too hot or too cold, which allows for other plants and animals to thrive. This will be discussed further in *Chapter 7*.

Even though plants take nutrients and water from the soil, certain plants can help to restore nutrients and maintain soil moisture. Some plants, especially leguminous plants such as pigeon peas and groundnuts, help to make the soil more fertile for other plants by fixing nutrients that can be taken up into plant roots. The presence of plants can also help to maintain soil moisture by preventing water from evaporating off the surface of the ground and facilitating water infiltration. The roots of plants make the soil more porous and less compact, allowing water to filter down into the earth after it rains. The shade provided by plants keeps the surface beneath them cooler, reducing evaporation.

Key Vocabulary:

- Stem
- Branch
- Leaves
- Roots
- Seed
- Flower
- Pollen
- Fruit
- Transpiration
- Photosynthesis
- Fertile Soil
- Sprout
- Seedling
- Re-sprout

CHAPTER 6: Introduction to Soil

As we now know from the previous chapter, plants are incredibly useful for humans and are a vital component of the environment. These plants, however, require the right type of soil to be able to grow and survive. Some of the properties of soil have already been discussed, but this chapter will explain them in more detail. This chapter will also look at some of the problems that must be dealt with in order to preserve the soil.

Soil formation and structure

Soil is a loose covering of particles that covers most of the land on earth. It is a mixture of rock particles, sand, clay, minerals, water, gasses, and organic matter such as decaying plant material. The type of soil differs from region to region and it depends on local rock material, climate, organisms and other conditions that are present.

There are several processes that help form soil. The first process involves breaking down bigger rocks. These larger rocks are called **parent material** and the process of breaking them down into smaller soil particles is called **weathering**. Weathering of parent material occurs because of wind, water, temperature, and chemical reactions. Plants can also help to break down rocks as their roots grow larger and deeper. Certain climates, such as the rainforests of the Congo, will cause parent material to weather much faster than climates like the Sahara Desert. The process of weathering can take hundreds of years and it takes a very long time to break down enough parent material to have a layer of soil deep enough to grow plants.

The living things, or **organisms**, that live under the ground are also very important to soil formation and composition. Some of these organisms, like insects, move the soil around and mix it together. Other organisms like plants, spread their roots down into the ground and influence the soil. When these organisms die, they begin to break down or **decompose**. Organisms that have decomposed become part of the soil and are an important component.

There are three important classifications for soil: texture, density, and porosity. The **texture** of the soil depends on the size of the particles that are there. Very small particles, like those found in **clay**, will make a very smooth, heavy soil. Large particles, like those found in **sand**, will produce a rougher or grainier soil texture. Soil in the middle of these two with lots of organic matter

is called **loam**. **Density** is a measure of how heavy the soil is per volume. One litre of dense soil will weigh more than one litre of less dense soil. The last classification is porosity. **Porosity** is a measure of how much air there is in the soil. A porous soil will have more air than a less porous soil. Pore space is the space that is not occupied by soil material and is basically pockets or holes in the soil that are filled with air or water.

All three of these classifications play a part in determining the moisture of a soil. **Moisture** is a measure of how much water is present in the soil. The more porous a soil is, the more moisture it can hold. Very dense soil will have less space for water. Porous soil allows rainwater to drain into the ground. Porous soil, however, can also lose water easily and so it is important that the soil is not too porous so that all of the water does not drain away. Therefore it is best to have a good mixture of soil in terms of porosity, texture, and density.

We know that plants require water to grow so it is important that soil has some moisture in it. Too much moisture, however, can cause the soil to become waterlogged. **Waterlogged** soil has too much water and it will suffocate and plants trying to grow there and cause them to die. Therefore it is important to keep the right amount of moisture for healthy soil.

Some plants prefer certain types of soil and plants that grow well in heavy, dense soil may not grow well in sandy, dry soil. In order to have successful crops, we must make sure we have the right plants for the soil we have, or the right soil for the plants we are trying to grow.

Soil fertility

Perhaps the most important factor contributing to healthy soil and plants is fertility. We know from *Chapter 5* that fertile soil is necessary for plant growth. We also know that **fertility** refers to the amount of nutrients that are in the soil and that plants need these nutrients just as much as they need water, air, and sunlight.

There are many nutrients that plants need to grow but perhaps the most important is nitrogen. These nutrients are essential for growth and the many functions that go on inside the plant. **Nitrogen** is very important to plants because it is essential but it is also very rare. We know from *Chapter 4* that nitrogen is the most abundant gas in the atmosphere. Unfortunately, plants cannot take in nitrogen when it is a gas and nitrogen that is not in gas form is

far more rare. Plants also do not have the ability to convert nitrogen from a gas into a useable form. Therefore they rely on small organisms that have the ability to fix nitrogen. **Nitrogen fixing** is the process of converting nitrogen gas into another form that can be taken up by plant roots. These small organisms live near the roots of plants and convert nitrogen gas for the plant in exchange for other nutrients and a safe place to live. Leguminous plants, such as groundnuts, host a lot of these organisms and are very good for increasing the amount of nitrogen in the soil.

There are many other nutrients that form fertile soil such as phosphorous, iron, calcium, and potassium to name a few. Most of these nutrients are found in the soil particles. When water enters the soil, some of these nutrients are dissolved into the water and then taken up into the plant through the roots.

There are many ways in which soil can lose its fertility. The first is caused when farmers grow the same crop year after year. Because that crop will need the same nutrients each year, eventually, the soil will run out of those nutrients and become infertile. This is why it is important to rotate crops so that the soil can recover, a topic that will be covered in *Chapter 17*.

The other way in which soil can lose its fertility is called leaching. **Leaching** is a process by which water that is draining into the soil dissolves the nutrients and carries them down deeper into the ground. Some areas with lots of rainfall experience heavy leaching. Leaching can cause soils to lose nutrients near the surface because the water carries them all away.

Soil erosion

Perhaps the biggest threat to having healthy soil is soil erosion. **Erosion** is the process by which soil is carried away by water or wind. We know that soil takes a very long time to build up. Unfortunately, all it takes is a heavy rain or a lot of wind to carry away hundreds of years of soil. This is bad for plants and farmers because it means that the soil that they would use is gone and nothing can grow there. Erosion on a large scale can lead to famine and hunger.

Erosion is also a problem because it can disturb some of the systems that occur in the environment. When a heavy rain falls, many metric tons of soil can be washed away. All of this soil washes into rivers and lakes clogging them in a process called **sedimentation**. Rivers that have experienced

sedimentation become very cloudy and dirty. Lakes can also become so full of soil that they fill up completely, reducing the amount of water available to the animals, plants, and humans living there.

The river on the left side of this bridge is filled in with soils that have been eroded as a result of deforestation.

Soil erosion has increased over the past few decades. Huge amounts of soil have been lost every year, leaving less and less land to grow plants on. This is not good for the environment or humans because fewer plants means fewer available resources for survival.

There are many reasons for this increased rate of erosion. The first is overgrazing. When we let our cattle and other livestock graze in the fields, they consume many plants every day. We know that plants are important for holding the soil in place and if too many plants are eaten, the soil will become less stable and can be blown away by the wind or washed away by the rain. When we let our livestock eat too many plants it is called **overgrazing**. In order to avoid overgrazing and prevent erosion, we need to make sure that we do not put too many animals on the land and make sure that wherever they are, they do not eat so much of the plants that the soil becomes unstable.

Another major cause of erosion is tilling. **Tilling** is the process used by many farmers to prepare land for farming. It involves using a hoe or a plough to tear up and turn the soil over. This process damages the soil structure and causes it to become unstable and prone to erosion. Tilling the soil too much can lead to massive erosion. There are many other farming practices that involve minimal or no tilling that not only protect the soil but can also produce more crops.

Finally, the largest reason for soil erosion is deforestation. When trees are removed and forests are cut down, the soil becomes less stable. Similarly, if forests are cut down, there is more wind, which can blow away the exposed soil, and rain will fall harder on the ground carrying away the fertile soil. This concept will be explored further in the next chapter.

Key Vocabulary:

- Soil
- Parent material
- Weathering
- Organisms
- Decompose
- Texture
- Sand
- Clay
- Loam
- Density
- Porosity
- Moisture
- Waterlogged
- Fertility
- Nutrients
- Nitrogen
- Nitrogen fixing
- Leaching
- Erosion
- Sedimentation
- Overgrazing
- Tilling

CHAPTER 7: Deforestation

One of the major threats facing the environment and the well being of humans on earth is deforestation. **Deforestation** is the removal of trees from a forest so that the trees or the land can be used for other purposes. Before reading this chapter, it is important to review the information in *Chapter 5* about plant basics.

Importance of trees and forests

As we know, plants are an incredibly valuable resource for humans, especially trees. They provide us with food, building materials, and fuel. Trees also provide many services such as clean air, stable soil, temperature regulation, and wind protection. Like any resource, however, we must make sure that we manage our trees sustainably so that we can ensure that we will continue to be able to benefit from them in the future.

In order for trees to be able to provide their many benefits, there must be a lot of trees. Each tree can only do so much and having only a few trees here and there is not enough to help protect the environment. Many species of trees will grow in large clusters, which cover a lot of land. These clusters are called **forests**. In order for us to experience the benefits that trees can provide, it is important that we protect entire forests.

We know from *Chapter 4* and *Chapter 5* that trees are able to take carbon dioxide, a greenhouse gas that can lead to climate change, from the atmosphere and replace it with clean oxygen, which we need to survive. Even though every tree is capable of doing this, there is so much carbon dioxide in the atmosphere that we need a lot of trees to remove enough to combat climate change. Therefore, protecting forests is crucial for protecting our air.

We also know from *Chapter 6* that trees are important for protecting the soil. Again, it takes many trees to make the soil stable and prevent it from being washed away by the rain. Similarly, in order to slow the wind down, there needs to be many trees to block it. One tree is not enough to prevent the wind from blowing away the soil or damaging houses. Once again, a few trees are not enough to regulate the temperature of the soil and without forests, the land can become too hot and dry to be useable.

Forests are also extremely important for creating the right conditions for other plants and animals to live. This is what is known as a **habitat** and it describes the natural home or environment that certain plants and animals need. Forests are important for creating habitats because they provide many services. Firstly, they provide places for animals to find shelter. Many birds build their nests in trees and other animals rely on the forest for protection from other animals. As we know, forests can keep the soil cool and moist, which allows other plants to thrive there.

Because forests provide such good habitats, they often have many different species living within them. This is called **biodiversity** and it refers to the variety of different plants and animals that live in a particular area. We know from *Chapter 1* that the environment is a complex place with many different components. All of these components are connected and they all rely on one another. Complex systems are a good indication of a healthy environment. Therefore, a forest with lots of biodiversity will generally be healthier. Biodiversity is important for protecting the environment and because forests can have high levels of biodiversity, they are worth protecting.

Causes of deforestation

If forests are so important, why are we seeing such high levels of deforestation? In the past few years, Zambia, like many places across the world has experienced very high levels of deforestation. Places, like Nakabwe, which used to have very thick and healthy forests, have been heavily deforested and now very few trees remain. There are many reasons for why deforestation has occurred so heavily in many places across the globe.

One of the main reasons for deforestation in Zambia is the production of charcoal. **Charcoal** is produced from large trees and is sold to households who use it for cooking and heating. Many people in Zambia have begun producing charcoal because it is a source of money for families. Unfortunately, because so many people are producing charcoal, many trees are being cut down and deforestation is happening at a very high rate. The problems associated with charcoal production will be discussed further in *Chapter 8*.

Another reason for deforestation is the production of timber. We know from *Chapter 1* that timber is wood that is used for building things such as houses or furniture. The process of collecting timber is called **logging**. Many places in the world are experiencing deforestation as a result of logging.

People practice logging so that they can get wood to sell for building material, furniture, artwork, and paper products. Even though logging is illegal in some areas, such as national parks and reserves, many people still practice logging. This has resulted in the loss of many trees across Africa and the rest of the world.

A precious tree being cut down for charcoal

Another cause of deforestation is agriculture. We know from *Chapter 1* that rapid population growth has meant that there is more demand for resources like food. Because of this, more and more land is being converted into fields on which we can grow more crops and raise more livestock for food. In order to prepare the land for farming, we must first clear it. This process is called **land clearing** and it involves removing anything that is on the land that would get in the way of farming such as rocks and trees. The increased demand for food and therefore the increase in land clearing is a major reason for why deforestation is occurring at such a high rate.

Mining is another process that causes deforestation. **Mining** is the process of removing valuable resources from deep in the ground. Sometimes, people dig tunnels into the ground but in other cases, like with many mines in the Copperbelt, people simply dig a giant pit in the ground. In order to do this, they must first cut down all the trees in the area. Mining can also cause forests to be lost because of the toxins that are released from deep in the ground during the mining process. When this occurs, the water becomes polluted and it can kill the trees growing around the area.

Another reason for deforestation is fire. Even though fires occur naturally, humans are responsible for starting many fires. Some people light **bushfires** to clear the land for farming or to chase out animals, which they can hunt and eat. This is a major problem because it not only kills big trees but can kill small seedlings that are trying to re-grow, preventing the forest from ever being able to come back naturally.

Dangers of deforestation

There are many problems and dangers that deforestation creates. As discussed in *Chapter 6*, erosion is a major problem for many reasons. If forests are removed, they can no longer keep the soil stable with the roots of trees. When forests are cut down, they can no longer protect the earth from the rainfall which can wash away all of the fertile soil in a single storm.

The loss of forests also contributes to air pollution. When we cut down trees, they can no longer capture carbon dioxide. Trees can only take in carbon dioxide when they are alive. Furthermore, cutting down trees can actually release carbon dioxide back into the atmosphere. When trees and other organic material decompose and rot, they release the carbon dioxide that is stored within them. This increases air pollution and contributes to climate change.

When we cut down forests we can also disturb the water cycle. We know from *Chapter 3* and *Chapter 6* that trees and plants play a part in the water cycle. When we remove trees, the rain that falls to the ground is less likely to be absorbed. Instead it runs off into rivers. This can leave the earth very dry. Similarly, we know that transpiration allows plants and trees to return water vapour to the air. When forests are cut down, they can no longer add this water to the air, which changes the water cycle.

Deforestation is also dangerous because it contributes to stronger winds and big temperature changes. Without forests to slow the **wind**, it can get very fast and erode the soil or damage our houses and buildings. Wind also spreads fire, which we also know is a problem for forests.

Deforestation also means that habitats will be lost. When habitats like forests are destroyed, many living things no longer have a place to live and they die. This is because they no longer have the right conditions to live in. This means that these areas lose their biodiversity and therefore the environment in these areas becomes less healthy.

Finally, if deforestation continues, we will not have any resources to use. We will have less timber for building things, less wood for charcoal and firewood, and less food to eat. Rapid deforestation must be stopped so that we do not lose the many resources and services that forests provide.

Preventing deforestation

Even though deforestation is a big problem, there are several ways in which we can protect the trees and keep the environment healthy. The main way we can stop deforestation is to stop cutting so many trees down. If we continue to cut trees at such a high rate, we will have no forests in the future. We can also look for different trees to cut down. As we know from *Chapter 5* some trees have the ability to re-sprout. Cutting these trees is not as bad because they can grow back in a few years and do not die completely meaning they can be reused year after year for firewood.

Of course, it is not possible to stop cutting trees altogether. Therefore, the most important way to combat deforestation is to plant new trees. Planting new trees is called **reforestation**. When we cut down trees, it is important that we plant new trees to replace the ones that we cut down. Like many other things in the environment, trees take a very long time to grow. So we must be sure to plant new ones before they are all gone. Reforestation is a sustainable practice because it allows us to cut down some trees and use them as a resource, but it also ensures that we will have trees in the future to benefit from. We should make every effort to plant as many trees as possible and encourage our friends and families to plant trees as well. Again, one tree is not enough. We should plant far more trees than we cut down so that we can combat deforestation and protect the environment.

Once we plant trees, however, we must make sure that they survive and grow into mature trees. We know from *Chapter 5* that seedlings are very delicate. If we do not care for them they will die and we will have failed to reforest an area. One of the main ways to protect seedlings is to prevent bushfires. Bushfires are very dangerous for seedlings because they cannot survive the fire like older trees can. Every time a bushfire is lit, many seedlings are killed. This is a problem for reforestation and should be prevented.

Forests are one of the most important features of the environment and without them we would have a very hard time finding resources and keeping the world healthy. It is crucial that we do everything we can to protect the trees and plant new ones whenever we can.

Key Vocabulary:

- Deforestation
- Forests
- Habitat
- Biodiversity
- Charcoal
- Logging
- Land clearing
- Mining
- Bushfire
- Wind
- Reforestation

CHAPTER 8: Domestic Energy

What is domestic energy?

We have discussed before that **fuel** is a very important resource for running machines, lighting and heating homes, and cooking. When fuel is burned, it makes energy. **Energy** can come in many forms such as heat, light, or power. When we light a candle, the flame we see is energy. When we use charcoal for cooking, the heat that rises from the charcoal is energy. When we use put petrol in the engine of a car, the car ignites the petrol and takes the energy there to power the car.

Energy is very important and we use it everyday in many different ways. This chapter will focus on domestic energy, or the energy that we use in our homes. This includes charcoal, firewood, and kerosene/paraffin. Unfortunately, these forms of energy are harmful to the environment and our health and can cause many problems. This chapter will cover these issues and then offer some alternatives.

Charcoal production

Charcoal is a very common source of energy in many parts of the world. Charcoal is used by many families living in cities in Zambia and the rest of Africa. **Charcoal** is a black substance that when lit, gives off a lot of energy in the form of heat and some light. Many families produce charcoal and sell it for money. Many other families buy charcoal and use it for heating or cooking. Even though charcoal is a very common form of energy in Zambia, it has many negative consequences that are worth knowing.

As we know from *Chapter 7*, charcoal is made from trees. The process of making charcoal involves cutting down trees, burying them in a mound of dirt, and then lighting them on fire. The production of charcoal has led to serious deforestation in many parts of Africa. Deforestation is a huge problem for the environment, as discussed in the previous chapter. Unfortunately, however, deforestation is not the only problem associated with charcoal.

One of the major problems is the gasses, or **fumes**, that are created when charcoal is being produced and again when it is being used in the home. We know from *Chapter 4* that there are many different gasses in the world.

Some of these gasses, like oxygen, are good for humans. Other gasses, however, can cause problems. The burning of charcoal gives off many different gasses. One of these is carbon dioxide, which we know is a greenhouse gas. Another fume that is given off by charcoal burning is carbon monoxide. **Carbon monoxide** is a toxic gas produced from the burning of fuel like charcoal and petrol, that can kill a person if too much is inhaled.

Many families cooking with charcoal are exposed to this toxic fume and can develop serious health problems such as lung disease and brain damage. Carbon monoxide is essentially a poison that is very dangerous because it cannot be seen or smelled. This is particularly a problem for women who are cooking everyday and are constantly exposed to these fumes.

Firewood

Zambian families that do not cook with charcoal generally cook with firewood. Like charcoal, firewood has several problems associated with its use. **Firewood** is gathered by collecting dry and dead wood of the ground, or by chopping down trees. Like charcoal, the use of firewood has led to the deforestation of many African forests. Although firewood is not sold as much as charcoal is, many people still rely on this source of energy for cooking and many forests continue to be cut down.

Firewood also has several problems just like charcoal. When we burn firewood, we release carbon dioxide into the atmosphere. Burning firewood can also cause health problems. The burning of firewood releases **soot**, or tiny particles of ash. When humans inhale soot, they can damage their lungs. Soot can cause diseases like asthma, bronchitis, and lung cancer.

Kerosene and paraffin

There are other forms of domestic energy that are not used for cooking. Kerosene, for example is used to light homes at night. **Kerosene** and **paraffin** are both made from petrol and are used to light lamps in the home. These fuels also release many fumes that are bad for human health. Many people develop diseases from breathing in the fumes produced by kerosene and paraffin. These sources of energy are also very dangerous. When kerosene is spilt, it can cause everything in the home to burn. Many people lose all of their property because of kerosene fires. These fires are almost impossible to put

out and they can cause serious injuries to those who are burned by them. Kerosene fires can permanently injure or kill people who are in them.

Alternative energy

There are many problems associated with these domestic energy sources but unfortunately many people do not have a choice when it comes to what energy source they use. Every household needs to cook and it is difficult to do anything like studying and preparing the beds without light. Because there is very little electricity in rural Africa, electric lights and stoves are not much of an option.

There are several ways in which we can approach the problems associated with these domestic energy sources. Firstly, families should look for other ways to make money besides producing charcoal. In Part Two of this guide, we will discuss how agro-forestry can be used to make money and allow people to stop producing charcoal. Being aware of the health affects of charcoal and firewood can also help reduce the negative impacts. If anything, families should try to plant as many trees as possible to replace the ones that they use for charcoal or firewood.

There are many products that exist that can help to protect the environment. Most of these products are very expensive, but once they are bought, they can actually save families money and time. One way to reduce the amount of firewood used for cooking is to buy an **efficient stove**. These stoves do not need as much firewood because they don't waste as much heat as regular stoves. Investing in one of these can reduce the amount of firewood that a family needs. **Solar lights** are a good alternative to kerosene. They use a panel that gets energy directly from the sun, which powers electric lights. These lights do not create flames or fumes and so there are no health hazards. Because solar lights can be used over and over again, families who have them do not need to buy kerosene and they can actually save money despite the fact that solar lights are initially expensive

Key Vocabulary:

- Fuel
- Energy
- Charcoal
- Fumes
- Carbon monoxide
- Firewood
- Soot
- Kerosene/paraffin
- Efficient stoves
- Solar lights

CHAPTER 9: Food and Nutrition

Food and energy

We know from *Chapter 5* that plants need nutrients, water, and energy to grow and survive. The same is true for humans. In order for us to live and be healthy, we need to have enough water, food, and nutrients. Water is essential for our body to be able to function. Without any water, we would die within 3 to 4 days.

Food is essential for survival in that it provides us with the energy we need to be active. When we eat food, a complex process called **digestion** is set in motion that breaks down the food and gives us energy. Digestion begins in our mouths where we chew our food, the first step in the process. After we swallow our food, it goes into our **stomach**, where it is broken down further by strong acids.

Food needs to be broken down so that it can be absorbed into our bloodstream and taken from our stomach to the rest of our body. The **bloodstream** is a network of veins that connect to every part of our body. Blood is circulated through the bloodstream each time our heart beats. As blood circulates, it brings things like oxygen, water, and nutrients, which are vital to our survival, to the parts of the body.

This process occurs within our bodies everyday and is crucial to our survival. Not eating enough food can cause us to become sick or weak. In order for us to have the energy to be productive during the day in school or while working, we must have enough food in our bodies. We also need food so that we can grow and develop. We convert the nutrients in our food into muscles, fat, and bones. Eating more than our bodies need, however, is also dangerous and can cause many other health problems such as obesity or diabetes.

Where does food come from?

The food we eat comes from many different sources. Primarily, food comes from animals and plants. Thousands of plant species are grown for food. Many of our foods come from the seeds of plants. Some seeds that we eat come in the form of **cereals** such as maize, wheat, and rice, or as **legumes**, such as beans and peas. We also eat many **fruits** that come from plants such as

lemons, mangos, guavas, and bananas. **Vegetables**, such as potatoes, cabbage, and onions, are another food source that comes from plants.

Animals also provide many forms of food that us humans eat. Food from animals comes either directly or indirectly. Whenever we eat the **meat** of fish, cattle, or chicken, we are eating food that comes directly from animals. There are many indirect sources of food, however. **Dairy** products, such as milk, cheese, and butter, come from the milk of animals. We also eat the eggs of chickens and the honey of bees.

The importance of nutrients

Eating enough food is very important for humans to be able to grow and have enough energy to live everyday. But equally important is what type of food we consume. Every food has different amounts of what are called nutrients. **Nutrients** are the components of food that our body needs, the rest of the material is not used and becomes waste.

Nutrients are divided into macronutrients and micronutrients. Macronutrients are the nutrients that we need large quantities of and include carbohydrates, fats, fibre, proteins, and water. Macronutrients are used to build body mass and provide energy. Micronutrients come in the form of minerals and vitamins.

There are many **minerals** that humans need to keep our body's functioning and prevent us from becoming weak or ill. Calcium, for example, is used to build our bones and Iron is important for healthy blood. **Vitamins** are another type of micronutrient, and they are also very important for our health. We must eat vitamins because our body cannot produce them naturally. Without vitamins, we can get diseases that can affect our bones, immune systems, and mental health. Similarly, not having enough vitamins can lead to some forms of cancer.

The food chain

In order for us to stay healthy, fight diseases and infections, and have enough energy to be productive at school or while working, we need to make sure that we consume all of the nutrients that our bodies require. This means having a balanced diet. Growing the right foods and raising animals in a certain way can help us to produce nutritious food that can keep us healthy.

All foods are connected and in order to keep ourselves healthy, we need to keep our foods healthy before we eat them. When we eat meat, we want to make sure that it comes from a healthy cow, which means that we have to make sure that the cow is eating healthy fodder. In order to understand this, it is worth discussing what is known as a food chain.

A **food chain** describes how energy and nutrients move from one living thing to the next when they eat one another. Every living thing, even humans, is part of some type of food chain. Some food chains are very complex and involve many different organisms and interactions. One simple food chain is as follows: grass provides food for small insects such as ants. Ants provide food for other animals such as chickens. Finally, chickens provide food for humans. This is a simple food chain but we can see that if humans depend on healthy chickens, then they also depend on the health of what the chickens are eating.

Food is crucial to our survival and making sure we get the right kind of food will help us to remain active and stay healthy. One way to do this is to practice some of the techniques that are outlined in Part Two of this guide. Understanding how all foods are connected will help us to grow better crops, raise healthier animals, and make our lives better.

Key Vocabulary:

- Food
- Digestion
- Stomach
- Bloodstream
- Cereals
- Legumes
- Fruits
- Vegetables
- Meat
- Dairy
- Nutrients
- Minerals
- Vitamins
- Food chain

PART TWO: AGRO-FORESTRY

CHAPTER 10: Introduction to Agro-Forestry

The History of Agriculture

Many people across the world participate in one way or another in some form of agriculture. **Agriculture** is a broad term used to describe the practice of growing crops or raising animals for food or other purposes. We know from Part One of this guide that animals and plants provide us with many of the resources that we use to make money and to survive. People have been practicing agriculture for thousands and thousands of years. It is one of the oldest activities that humans partake in.

The story of agriculture has traditionally been one of "man against nature." For thousands of years, humans have tried to conquer nature and bend it to their will. In the struggle to provide enough food and materials for our growing population, humans have developed many technologies and methods for changing the natural world so that it provides what we need.

Technologies like the plough and complex machines such as tractors have changed what humans are capable of in terms of altering the environment. Scientists and engineers have developed methods for artificially changing things like the fertility of the soil or the physical properties of plants. Many species have been genetically altered so that they can grow faster, survive under harsher conditions, and produce more fruit or seeds. Technologies such as irrigation systems and mechanized harvesting have allowed us to turn fields into massive agricultural operations like the sugar plantations in Mazabuka.

It should be said that many of these technologies have been tremendously beneficial to the human species. Our population has been able to grow at an incredible rate and in many places around the world extreme

hunger has been reduced. Without these technologies, our species would likely not have made the advancements that we have.

In the past few decades, however, many scientists and agricultural experts have been reviewing these technologies. It is now becoming clear that while these methods enabled us to feed many more people, they are also causing serious environmental problems. Even though these technologies may seem beneficial, they have made many things worse. We know from *Chapter 1* that all resources depend on the environment, including food so when we harm the environment we can reduce the amount of food we have.

Not only are these technologies destructive to the environment, but the systems surrounding them are destructive in other ways. For example, very few rural farmers can afford the expensive products and machines that have helped wealthier farmers. Countries that have access to these technologies are able to outcompete smaller farmers because they can produce more food and sell it at a lower cost all over the world.

The agricultural methods that have existed for the past hundred years or so have had many negative impacts on the human population and the natural world. Therefore, it is necessary for us to find new methods to ensure that we do not destroy the environment.

What is agro-forestry?

Fortunately, just as agriculture practices have changed in the past, they can still change in the future. Many alternative agricultural methods have been developed in the past few years that have produced many benefits. These new methods are focused on sustainable practices. **Sustainability** is essential for agriculture because without food and animal products, we would not be able to survive. Therefore, we must ensure that we do not ruin our ability to provide for ourselves in the future.

One of the methods that have been developed is called agro-forestry. **Agro-forestry** is a sustainable form of agriculture that focuses on growing crops in an environmentally friendly way by incorporating trees into the farm. Agro-forestry aims to protect the environment from things such as deforestation, while also seeking to improve the livelihoods of the people who practice it.

The agro-forestry programme that is covered by this guide was developed over several years by Bornface Hangala and the Taonga Office at the Chikuni Mission in Zambia. The programme was developed in response to the many social and environmental issues that face the people in this part of the world. As this guide will show, this programme has many benefits for the people who practice these techniques. It can also have a positive impact on the environment in the area that has experienced a lot of destruction over the past few decades.

While the programme was developed in Chikuni, many of its components and methods are applicable to other areas of the world. Some of the principles behind agro-forestry are universal and can be practiced on any farm on earth. Therefore, understanding the methods in this guide can help to make us better protectors of the environment in Zambia and the rest of the world.

Why is agro-forestry useful?

There are many things that families in rural Zambia and elsewhere need. Of these, food, shelter, firewood, and a source of income are probably the most important. Unfortunately, many of the environmental problems that Zambians face are the result of people trying to obtain these resources. For example, In order to produce food, many farmers have adopted practices that lead to soil erosion. In an effort to cook their food, many trees have been cut down leading to the issues associated with deforestation. Many Zambians have begun to produce charcoal in an effort to make more money, which contributes to poor health, air pollution, and deforestation.

Agro-forestry offers an excellent solution to many of these problems. Because agro-forestry is sustainable and does not impact the land as heavily as other methods, farmers who practice it will not add to things such as soil erosion. Similarly, some of the plants that can be grown in an agro-forestry garden can be used for firewood over and over again because they grow back so quickly. This helps to reduce deforestation.

We know from *Chapter 9* how important having a balanced diet is. Agro-forestry can also benefit people by providing them with nutritious foods that they need to survive and remain healthy. Many of the trees that are incorporated in an agro-forestry garden have environmental benefits as well as nutritional value for humans or livestock.

Agro-forestry is also useful because it helps people to use resources sustainably. Agro-forestry gardens waste less water and nutrients. Similarly, when things in the garden die, they can be reused and turned back into healthy soil. Pretty much everything in the agro-forestry garden can help to conserve resources and make being sustainable easy for any farmer.

Because fewer resources are needed, farmers can save money. Agro-forestry techniques do not require things like chemical fertilizers or pesticides. Therefore, agro-forestry farmers do not need to spend money buying these products. Farmers not only save money, but they can also make more money when they practice agro-forestry. This is because they have more products to grow and sell and techniques to make their products last when they are waiting to be sold.

Agro-forestry is an incredibly useful practice for families across Zambia and the world. Not only can it help protect the environment and help us become sustainable, but it can also improve a family's health and income. Practicing agro-forestry requires a good understanding of many techniques and why they are being done. The rest of this guide will be devoted to explaining the many processes that are needed for agro-forestry as well as explaining why they are important.

Key Vocabulary:

- Agriculture
- Technologies
- Sustainability
- Agro-forestry

CHAPTER 11: Starting an Agro-Forestry Garden

The most important thing that any person practicing agro-forestry needs is land to be used as a garden. Before any planting, growing, or harvesting can take place, a farmer must ensure that he or she has a suitable location for a garden that is well located and safe. The **garden** is where the majority of the agro-forestry activities will take place and it will be home to the many plants that will be grown and cared for.

Selecting a location

Because the garden is so important, it is critical that a good location is found for it. When selecting a location, one should pay attention to the slope of the land and the security of the garden.

The **slope** of the ground must be taken into consideration because the flatter the ground, the better the location. This is because flat ground is easier to work on and easier to plant plants on. Flat ground also holds more water because it is unable to run downhill. Having water run off a garden can cause soil and other materials to be washed away. Similarly, if the water is running off the garden, it is not being absorbed into the soil and cannot be used by plants.

The **security** of the garden is also very important. A garden should be placed in an area that can be protected easily. Having a garden close to a school or a centre is a good way to make sure of this. Security means keeping out unwanted animals that might eat the crops or other people who might steal them.

Water source

The next important factor to consider is the availability of water. We know from *Chapter 3* and *Chapter 5* that water is vital for plant growth. Therefore, a garden must have access to some water source or else it will not be successful. The process of diverting or adding water to a garden or field for the purpose of growing crops is known as **irrigation**. Irrigation is necessary for plant growth and ensuring that it can be done effectively is important when determining where the best place for an agro-forestry garden is.

We also know from *Chapter 3* that water comes from many different places. While rainwater is an excellent source of water and is good for irrigating crops, it is an unreliable source. Half of the year, rain does not fall, and even when it is the rainy season, the rain can come at any time and cannot be controlled. Therefore, water must be gathered from deep within the ground or from rivers and lakes.

The best water source for irrigation is a borehole. **Boreholes** are narrow pipes that go over 40 metres down into the ground to access groundwater. Boreholes are a very reliable source of water because they rarely go dry. They can also provide very clean water that is not polluted or contaminated, although some water from boreholes is not good for irrigation. Boreholes use a **pump**, which uses pressure to push water up to the surface from deep within the ground. Unfortunately, drilling boreholes and installing pumps are both very expensive. Therefore, communities should share boreholes. This is why locating a garden near a school or centre is useful.

Children using a pump attached to a borehole to retrieve water from deep underground

Another method for accessing groundwater is to use an open well. An **open well** is much wider than a borehole but does not go nearly as deep. Open wells are dug until groundwater begins to fill them up. They are often walled with bricks or concrete to prevent them from collapsing. The water in open wells is drawn up using a bucket. It is important that those using open wells keep them clean. If animals fall in and die, they can contaminate the water. Similarly, many diseases can grow in open well water if they are not managed well. It is best to have a cover for the open well if it is being used.

Of course, if a borehole or open well is not available, water must be gathered from rivers or lakes. If this is the case, then gardens should be located where people can access **stream/river water** or where there is a dam or lake nearby where people can collect **lake/reservoir water**. Although this method involves a lot of work and time spend transporting water, it can still be used for an agro-forestry garden.

Soil measurements

Once flat ground and a water source have been found, it is important to make sure that the soil in the proposed site is good for an agro-forestry garden. We know from *Chapter 6* that there are many types of soil, each with different characteristics with regards to texture, density, and porosity. Certain plants enjoy different types of soil, so it is very important to analyse what type of soil is present in the proposed garden site. A **soil analysis** is a necessary procedure when creating a garden and will help to make it successful by identifying the type of soil that is present and by extension, the plants that will successfully grow there. Even if flat land and a water source have been secured, if the soil is not good for a garden then the garden will not be successful.

To perform a soil analysis, several factors must be taken into account. The first is the **soil depth**, which will tell us how deep the good, useable soil goes. In other words, how deep can the roots of a plant grow before they hit rocky or gravely ground. Some plant roots need to grow very deep down into the soil while others tend to spread out just under the surface. Therefore, understanding where the deep soil and shallow soil is will help to plan what types of plants to grow.

The next important factor is the **soil characteristics** themselves. Again, because plants have many different soil preferences, it is important to make

sure that we know what soil is present. Some plants, such as Moringa, prefer heavy soil, which is dense and has lots of clay. Other plants may prefer sandier soil that is less compact and more porous.

Many different soil samples should be taken around the proposed site and the specific characteristics and depths should be recorded and mapped. This way the plants can be planted where they are most likely to grow. This can reduce the amount of alteration the farmer has to do to the land before planting. This will also help to reduce the amount of work a farmer has to do in the future to keep the plants alive and healthy.

Clearing the land

If a good location has been found that is flat, has access to water, and has good soil, the next step is to begin to prepare the site. The first thing that needs to be done is to map the garden site. **Mapping** the site will identify the boundaries of the garden, where the fences need to be placed. The soil records taken previously should be incorporated into this map as well.

It is likely that within the mapped area, there will be many different plants already growing there. While many of these will need to be cleared out of the area, it is important that some of them are left alone. The reason for this is that some plants and trees can be very beneficial to the health of the garden if they are left there.

Some examples of plants that should be kept are wild fruit trees and other tall trees. We know that trees have many benefits and integrating trees with the garden is the central theme of agro-forestry. Not only can wild fruit trees be harvested for fruits to eat or sell, but they can also be useful for maintaining soil moisture. Tall trees are important and should be left, especially around the edges of the garden because they help to break the wind, which is important for protecting the plants and soil within the garden. Trees can provide a home for species like bees, which are very important for the plant lifecycle because they help to pollinate the plants and help them reproduce. The trees also provide habitat for natural predators, which help to control pests like rats and insects, a concept that will be covered in *Chapter 18*. Finally, many of the trees that grow in this area are good for increasing the fertility of the soil because they are nitrogen fixers. See *Chapter 13* for more information on fertilizer trees.

Once the beneficial trees have been identified, all of the other vegetation should be removed. This process is called **land clearing** and it involves eliminating the vegetation that exists within the garden site so that space and resources can be made available for the plants that will be grown and harvested. Land clearing involves uprooting the unwanted vegetation by hand or using tools like handpicks, axes, and spades. The plants must be removed completely, including their roots so that they do not grow back in the future. Once the unwanted vegetation has been uprooted, the holes that are left should be filled in to make the ground flat again.

Once all of these steps have been completed successfully, the agro-forestry garden can begin to be built and cared for!

Key Vocabulary:

- Garden
- Slope
- Security
- Irrigation
- Borehole
- Open well
- Stream/river water
- Reservoir/lake water
- Soil analysis
- Soil depth
- Soil Characteristics
- Mapping
- Land clearing

CHAPTER 12: The Living Fence

As we know, security is a very important component for an agro-forestry garden. Security means several things, all of which are worth considering. The first and most obvious reason for having a secure garden is to prevent theft. A successful garden full of healthy crops makes a good target for people looking to steal food and materials. Security also means protecting the garden from animals, such as pigs and cattle, which might get into the garden and eat or trample the produce. Finally, security also means protecting the garden from things such as the wind, which can damage the plants growing within the garden.

In order to ensure the security of the garden, the best thing to do is to construct a living fence. A **living fence** is a multipurpose fence that can have the same benefits as a traditional fence as well as many others. The reason the fence is called a living fence is because it is constructed from living trees and shrubs that grow and live with the plants inside the garden.

A traditional fence constructed using wood or wire is useful for keeping out thieves and animals, but does not have the added benefits that a living fence brings to the garden. A living fence is an effective way to keep out unwanted people and animals, but it is also more effective at keeping the wind away. Stands of trees that slow or stop the wind are called **windbreaks**. Fences constructed of wood or wire are not big or strong enough to break the wind as effectively as a fence made of trees is. Another advantage that some living fences provide is fire protection or what is called a **firebreak**. Some trees, such as gliricidia are able to protect areas from fire because they eliminate bushes and shrubs that burn easily and spread fire.

A living fence is also beneficial because it can provide additional resources to the garden. For example, fences made from fast growing plants, which can re-sprout, can be used for firewood. This is because branches can be cut down and used without killing the entire plant. These branches will grow back quickly, providing a sustainable source of firewood. As mentioned before, many trees that can be incorporated into the living fence are excellent **nitrogen fixers**, which can improve the soil fertility and add valuable nutrients that the plants within the garden need to survive. Living fence plants can also help provide **biomass**, which is organic matter that can be used for fertilizer and compost and comes from fallen leaves and other plant litter. These leaves

can also be used as **fodder** or animal food. Some plants, such as Jatropha trees, can be used to make seed oil, which can be sold.

A view of a living fence from inside the garden with adult Jatropha trees on the right, and a hedgerow on the left.

Establishing a living fence

Now that the benefits of the living fence have been clearly outlined, we can begin to learn about how to establish a living fence. One of the disadvantages of a living fence is that it takes a long time to grow into its full form. The living fence may take a few years before it is fully grown. During this time, the garden needs to be protected. Likewise, the plants that are being grown for a living fence need to be protected until they can grow large enough. Therefore, it is necessary to construct a **temporary fence** to give protection while the living fence is being grown.

Constructing the temporary fence is the first step in creating a living fence. The temporary fence can be constructed using wood or wire fencing materials and should be large enough and strong enough to keep out

unwanted animals. The temporary fence should be placed around the perimeter of the garden, but should be between one and two meters from the space where the living fence will be grown. This will allow enough room for the living fence to grow and develop. Once this temporary fence has been constructed, preparation for the living fence can begin.

The next step is to map out where the living fence will be grown. Again the living fence should be placed about a meter or two from the inside of the temporary fence. Once this area has been marked, the next step is to remove all of the vegetation that is in the area. Much of this vegetation should have been uprooted during the land clearing phase discussed in *Chapter 11*. Any trees or shrubs that could contribute to the living fence should be left alone. It is important to eliminate the unwanted plants so that the living fence does not have to compete for nutrients, water or sunlight with the other plants.

The next step is to dig a trench where the living fence trees will be planted. The depth of the trench needs to be deep enough to protect the seeds or seedlings but not so deep that they cannot grow. The depth of the trench will be determined according to what plants will be grown as part of the living fence.

Once the trench has been dug, the next step is to plant the living fence plants. Once they have been planted in the soil, they should be covered. As the living fence grows, it is crucial that it is cared for. The fence should be watered consistently. At the beginning of the development stage for the living fence, liquid manure and compost should be added to the area to help fertilize the soil and promote the growth of the plants. The process of making and applying liquid manure and compost will be discussed in *Chapter 13***.**

One of the most important aspects of growing a living fence is monitoring. **Monitoring** means checking on the progress of the living fence and observing how well it is establishing. If, for example, a section of the fence fails to grow, an assessment should be done to determine why it failed. After identifying the cause, that section of the fence should be replanted as soon as possible. Monitoring should always be done, even when the fence has grown in. Observing the trends in and around the garden will help to ensure that problems are avoided or solved before they can cause too much damage.

Living fence materials

Now that we know some of the basics on how to establish and care for a living fence, we can begin to discuss some of the materials that are needed and the plants that can be grown. As we know, a temporary fence is needed at the very beginning of the process. If it is possible, the temporary fence should be constructed of metal wire fencing material. This material provides the best protection and can even be left in place after the living fence has been established. If this is not possible, the temporary fence should be constructed using local materials such as wood and branches. It is important to make sure, however, that the materials used do not harm the garden. This can happen if they may cause the soil to become too acidic and kill the plants.

This same problem must be taken into account when determining what plants to leave in and around the garden during the land clearing phase. Some plants that may appear to be good candidates for a living fence may actually be harmful. For example, some plants can make the soil too acidic. Others may require too much water, which will cause the farmer to use extra water to ensure that the actual crops do not die.

There are many useful plants for a living fence. Generally, these plants are fast growing and can grow very tall. Some examples are Jatropha, various leucaena species, and gliricidia plants. Not only do these plants grow quickly, but they can also grow very tall and make for a good windbreaks and firebreaks. As discussed before, many of the plants used for living fences can also provide extra resources such as oils, firewood, or fruits.

Once the living fence has been planted and given enough time to establish fully, the garden will be well protected and will benefit from the many advantages of having a living fence.

Key Vocabulary:

- Living fence
- Windbreak
- Firebreak
- Nitrogen fixer
- Biomass
- Fodder
- Temporary fence
- Monitoring

CHAPTER 13: Fertilization and Compost

Importance of fertilization

As we discussed in *Chapter 5* and *Chapter 6*, soil fertility is one of the most important factors for the growth of healthy plants. Soil that is **fertile** is full of nutrients that plants need to grow and stay alive. Without these nutrients, plants are smaller and less productive. Most of these nutrients, such as phosphorous, calcium, potassium and iron, are found in the soil and are taken up through the plant roots. But perhaps the most important nutrient for plants is nitrogen.

Nitrogen is important because it is very rare and is difficult for plants to obtain. We know from *Chapter 4* that nitrogen gas is the most abundant gas in the atmosphere, making up 78% percent of its total composition. Even though nitrogen is very abundant in the air, plants cannot use nitrogen in its gas form. Therefore, the nitrogen in the air must be converted into another form so that the plants can use it. When nitrogen gas is converted into a useable form, it is called a **nitrate**. There are many different types of nitrates but no plants are able to create them on their own and because of this they need some help.

The process of adding nitrates and other valuable nutrients to the soil to promote plant growth is called **fertilization**. The nutrients that are being added are called **fertilizers** and they include things such as nitrogen and phosphorous. For many centuries, farmers have struggled to find ways to increase the fertility in the soil so that their crops can grow bigger and be more productive. Fertilization is a very important aspect of this agro-forestry programme and must be understood completely before the garden is actually started.

Chemical vs. Natural fertilizers

There are two different forms of fertilizers available to farmers today: natural and chemical. It was only within the last one hundred years that scientists figured out a way to convert nitrogen gas into nitrates using technology. Before then, nitrates could not be created by anything other than the natural processes that already existed. When the technology was discovered that allowed humans to make nitrates from nitrogen gas, **chemical fertilizers** were born. These chemical fertilizers were revolutionary for many farmers across the world and they allowed farms to become far more

productive. Chemical fertilizers can be concentrated to include high amounts of nitrates and other nutrients that plants need to grow.

While chemical fertilizers are a tremendous scientific breakthrough that allowed humans to produce far more food than ever before, they also brought with them some very negative consequences. Firstly, the process of creating chemical fertilizers uses a lot of fossil fuels and creates pollution. Furthermore, farmers using chemical fertilizers often add far more than is needed by the plants they are growing. This over-fertilization of the soil can actually damage it in the long run. The excess nitrates can reduce the effectiveness of the organisms that naturally convert nitrogen gas into nitrates. In many cases, soil that has been over fertilized with chemical fertilizers can turn to **hardpan**, which is a term used to describe land that is too hard for plants to grow or for water to penetrate.

In addition, excess fertilizers that get washed away when it rains end up flowing into rivers and eventually into the lakes and oceans around the world. This is a problem for humans because water with too many nitrates in it is poisonous for us and we cannot drink it. This is also a problem because when these fertilizers reach the ocean, they cause plants like algae to grow very rapidly, covering the water with plant life. When all of the algae die, they begin to decompose. The process of decomposition involves a lot of oxygen, which as we know is important for all living things, including fish. Because there is so much algae decomposing, there is not enough oxygen for the fish in the area to survive and many fish die. This entire problem, called **eutrophication** is a major issue in many places across the world where chemical fertilizers are used in excess.

There are many negative impacts that chemical fertilizers have on the environment and therefore this agro-forestry program fully discourages their use. Not only are these chemical fertilizers bad for the environment, but they are also very expensive to buy. Instead of paying a lot of money for fertilizers that are bad for the environment, this programme encourages people to use natural fertilizers. **Natural fertilizers** come from dead plant material and animal manure and can be used as an alternative to chemical fertilizers without causing any serious environmental damage. Natural fertilizers are sustainable because they involve recycling materials and produce almost no waste. The next section of this chapter will deal with how to produce and apply natural fertilizers to help promote healthy plants and protect the environment.

Creating natural fertilizer

As we know, fertilizing the soil of an agro-forestry garden is essential for the success of the programme. Therefore, even before planting can take place, farmers should know the different types of natural fertilizer and understand how to make and when to apply it. If natural fertilizer is prepared improperly or applied at the wrong time, it can actually harm the plants that it is intended to help. Therefore careful attention must be paid to the following procedures.

Animal Manure

The first type of natural fertilizer is **animal manure**, or the excrement of animals. Animal manure is readily available anywhere there are cattle or other livestock. Because animal manure is largely made of the plants that the animals ate, it has many of the components that plants need to grow. Basically, whenever we use animal manure, we are recycling the plant parts that were not absorbed into the animal during digestion.

Animal manure can be applied directly to the planting area or mixed in with the soil before planting, and it requires very little preparation. Farmers can create piles of animal manure to be used as natural fertilizer. Before applying animal manure, however, a farmer must check the temperature of the pile before applying it to the crops or mixing it with the soil. If the pile is warm or hot on the inside, it is not ready to be applied. This is because the manure is “active”. In other words it is decomposing. When organic matter like animal manure undergoes **decomposition**, there are many chemical reactions and microbes acting to break the material down. If the manure is applied when it is still decomposing, it can damage or kill the plants.

Animal manure should be mixed in with soil or added to the planting area before the plants are placed in the soil. It can also be added after plants have begun to grow, however.

Liquid Manure

The next type of natural fertilizer is called liquid manure. **Liquid manure** is made from animal manure but is converted into a liquid form so that plants can take it up quickly and easily.

In order to create liquid manure, about 25 kilograms of solid animal manure should be added to a cloth or mesh sack. The sack should allow water to pass through it but not let the solid material within escape. The next step is

to immerse the bag with the manure in it in a drum of water. The drum should be placed in the sun so that the liquid manure can ferment. The mixture should be left in the sun for a minimum of 7 days so that all of the nutrients in the manure can be dissolved into the water. The process works like a giant teabag that allows the nutrients to seep into the water leaving chaff behind in the sack.

When the mixture has been allowed to ferment for enough time, the sack can be removed. The chaff inside the sack should be added to compost piles or used as mulching material. The mixture left in the drum is now ready to be used as liquid manure fertilizer. Liquid manure should be applied to plants right after they have sprouted and during the middle stages of their development. Because liquid manure is a liquid, it is very easy for plants to take into their roots, which speeds up the process of nutrient uptake and encourages healthy plant growth in the early stages.

Compost

The last type of natural fertilizer is called compost. **Compost** is basically decayed or decomposed organic material that can be added to soil to make a healthy growing medium for plants. Compost can be made in a heap or in a pit, but this guide will focus primarily on the heap method. Basically any organic material coming from plants or animals can be turned into compost and therefore it is a good way to recycle things in the agro-forestry garden. Things that can be broken down and decomposed naturally are called **biodegradable**. In *Chapter 2*, we discussed purchasing biodegradable products as a way to prevent pollution. These same products can also be made into compost.

Compost is created by forming a heap of biodegradable organic mater and dirt and allowing it to decay. The first step to creating a compost heap is to clear an area of land several square metres large. Then, twigs should be laid on the cleared ground. The next step is to add a layer about 40 centimetres thick of compostable material. This layer can include grass, chaff, any discarded plant material, or anything biodegradable. After this first layer has been added, water should be poured over the heap and the layer should be covered with dirt.

To build the heap, more layers of compost material should be added on top of one another. Each new layer should be about 40 centimetres thick and once it has been added, it should have water poured over it and be covered in

dirt. Once the compost heap has reached the desired height, it should be covered completely with dirt and left to sit.

After three days, the heap needs to be checked to see if the process of decomposition has begun. In order to test this, a stick should be inserted into the middle of the pile and left for a few minutes. When the stick is removed from the pile, the tip should be felt for warmth. If the tip of the stick is warm, then the process has begun. If it is cool, then more water and soil should be added to the heap.

Once the process has begun, the heap should be left for 14 days. On the 15th day, the heap needs to be turned. In order to do so, a new area should be cleared and new twigs should be laid down. Then, the heap should be transferred to the new location and re-heaped. The new heap should be covered with dirt and moisturized again and then left for another 14 days.

By the end of those 14 days, the heap should have been decomposing for about a month. The next step is to re-heap the entire pile one last time in another location. After another 3 days, the pile should be checked with a stick to see if the process is complete. This time, the stick should feel cold when it is removed from the pile. If it is not cool, the pile should be left and rechecked until the stick is no longer warm. When the process is complete and the stick is cool, the compost is ready to be used.

It is important that compost is not added too early for the same reasons that it is important not to add manure too early. Doing so can damage or kill the plants. Compost should be used to create good soil and should be added during the early stages of growth. It is a good base for growing and is rich in many nutrients.

Fertilizer trees

While using natural fertilizer is a necessary component of this programme, it is not the only way to increase the fertility of the soil. As we have discussed before in *Chapter 5* and *Chapter 6*, we know that some plants are good nitrogen fixers. These plants are called **fertilizer trees**. While the trees themselves are not actually responsible for producing nitrates, they provide a good home for the organisms that do. These organisms are called **nitrogen-fixing bacteria** and they are able to convert nitrogen gas into nitrates which can be taken up by the plants.

Even though these organisms live in the soil in many places, they prefer to live in certain environments over others. Some plant species provide this type of habitat. Down in the roots of these plants, the nitrogen-fixing bacteria thrive and actually infect the root area. These plants allow the infection because they are able to absorb some of the nitrates that the bacteria generate. In exchange, the plant provides shelter and energy to keep the bacteria alive.

These fertilizer trees then move the nitrates into their stems, branches, and leaves, making them very rich in this rare nutrient. When fertilizer trees drop their leaves or die, they are able to return the nitrogen to the soil. As the leaves and branches of fertilizer trees decompose, they release the nitrogen that is packed into them. This makes the soil around these trees very fertile.

The most common fertilizer trees are the **leguminous plants,** which produce beans or peas. Plants like pigeon peas, cowpeas, fish poison, leucaena, gliricidia, sesbania, and moringa are excellent fertilizer trees and should be incorporated into every agro-forestry garden. We already know that many of these plants provide many benefits for the garden such as wind and fire protection, moisture retention, and firewood.

Many of these trees also provide good food for animals and are known as **fodder trees**. Plants like the leucaena are a good example of this. When animals eat the leaves of these trees, also eat the nitrogen that is held within them. Therefore, the manure of these animals will be extra rich in nutrients. Similarly, these leaves make an excellent addition to any compost heap.

Key Vocabulary:

- Fertility
- Nitrogen
- Nitrates
- Fertilization
- Fertilizers
- Chemical Fertilisers
- Hardpan
- Eutrophication
- Natural fertilizers
- Animal manure
- Decomposition
- Liquid manure
- Compost
- Biodegradable
- Fertilizer trees
- Nitrogen-fixing bacteria
- Leguminous plants
- Fodder trees

CHAPTER 14: Nurseries and Shades

By now we have covered several of the important issues surrounding agro-forestry. So far, most of the topics have related to preparing a site for the garden. These have included finding a location for a garden, creating a living fence, and preparing various natural fertilizers to be fed to the plants. There is one last important bit of work that must be completed before the garden can be planted, which will be the topic of this chapter.

We know from *Chapter 5* that aside from nutrients and sunlight, plants require two other basic things: water, and a suitable temperature. While water can easily be added to plants if they are getting dry, it is important to make sure that we are conserving water and keeping the **soil moisture** constant. Allowing the soil to dry out and then flooding it with more water is not necessarily the best way for a plant to get water. It is better if the soil moisture is kept somewhat constant so that the plants can have enough water to sustain themselves.

Temperature is much more difficult to control in a garden. We know from *Chapter 4* that climate change is causing many things in the environment to change. One of these things is the temperature. With greenhouse gas emissions and global warming on the rise, we are seeing increasingly hotter summers, which can cause crops to lose water faster and dry up. On the other side, we are seeing colder winters that bring **frost** to our farms and kill our crops. Even though we cannot control how the temperature changes, we can help to protect our crops from these changes, especially when they are first starting to grow.

In order to do so, we need to create what is called a nursery. A **nursery** is a place where young plants can be protected from things like changing temperatures and moisture contents. The construction of a nursery can help to ensure that right from the beginning of their lives, the plants in our agro-forestry gardens are healthy and strong. Nurseries can be used for both trees and vegetables, both of which will be covered in this chapter

Constructing a tree nursery

When we begin to grow our young trees, we will be placing them in poly-bags, which are essentially small pots for the plants to begin their lives in. The small poly-bags are filled with soil and have seeds planted in them. This

will be covered further in *Chapter 15* but for now it is important to know that the poly-bags must be managed properly while they are still in the nursery.

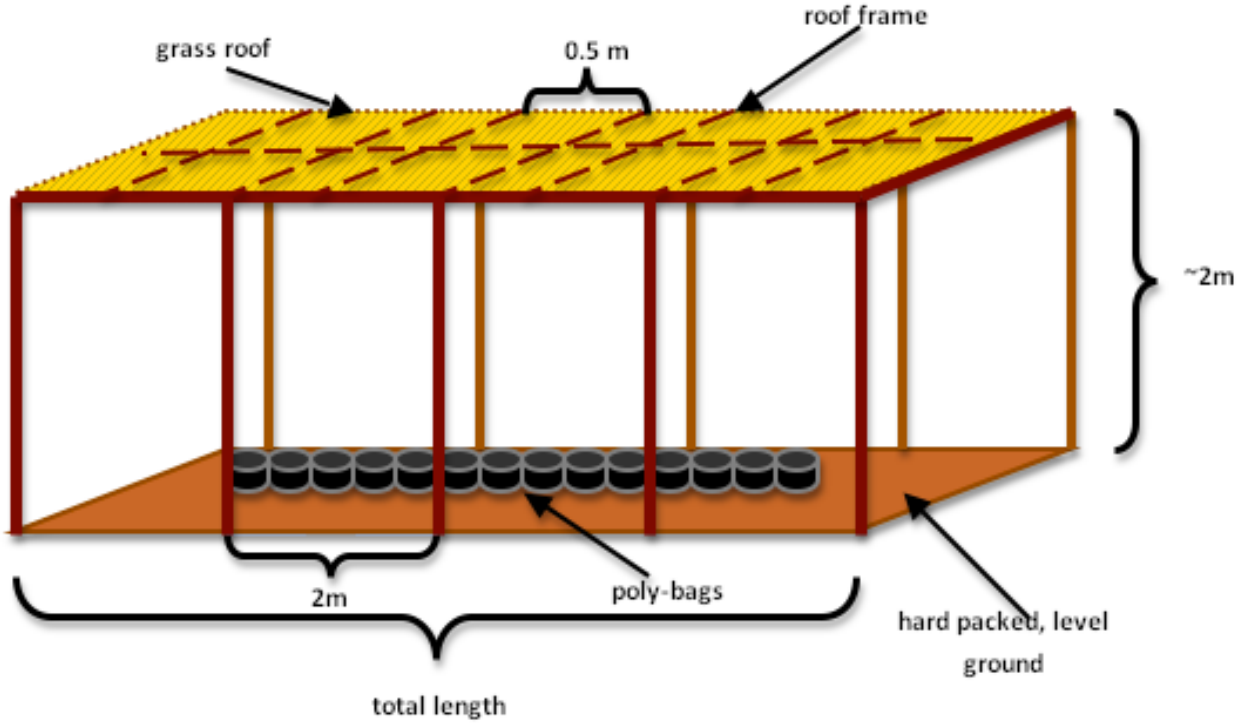
The first thing that needs to be done with a **tree nursery** is to make sure that the ground is level. Once the area that will be used for the nursery has been identified, the ground within that area must be flattened as much as possible. The dirt should then be packed down so that it is hard and secure. The reason for this is because in order to make sure the poly-bags and their seedlings are managed properly, we must ensure that they will not tip over. If they tip over, the plants can grow crooked within them or worse, they can spill out and die. Therefore, levelling the ground using a spade and whatever other tools are needed is very important.

The next step of constructing a nursery is to build a shade. A **shade** is a structure that has a thin grass roof and no walls that is used to cover the nursery and protect the plants underneath. The shade helps to do many things for the plants. Firstly, it helps to regulate the temperature of the nursery. If the plants are exposed to too much sun, they will get too hot. The shade helps to reduce the amount of heat that can reach the plants from the sun. At night, the shade helps to keep the temperature underneath it warmer. It does this by trapping the heat from the day and keeping it from escaping into the night. A shade also helps to prevent water from evaporating in the sunlight as well.

To construct a shade, a series of poles must be cut from branches to form the frame of the shade. The branches should be between 1.8 and 2.5 metres long after they have been stuck into the ground, and should have a fork end that makes a “Y” shape. To plant them in the ground, a series of holes should be dug around the perimeter of the nursery. Of course, the size of the nursery and shade depends on how many plants are being grown. The holes along this perimeter should be placed roughly two metres apart and should be dug about 40 centimetres deep. After the holes have been dug, the poles can be planted within them and buried. It is important to make sure that the poles are sturdy and solid so that they will not collapse.

After the poles have been placed in the ground. The rest of the frame should be made from long twigs. These should be laid around the edge of the shade as well as across it to form a latticework of twigs, which the grass will be placed on. There should be about half a metre between each of the twigs that make up the roof shade. These should then be tied to the poles to make sure they do not fall off in the wind.

Tree Nursery Shade



Finally, grass should be placed on the roof frame to finish constructing the shade. It is important not to put too much, or too little grass on top of the shade. If the grass is too thick, not enough sunlight will get through, but if it is too thin, the shade will be unable to regulate the temperature. The grass should be placed such that a small amount of sunlight gets though but keeps most of the nursery in the shade. The grass should be tied down to the frame to keep it from blowing away in the wind.

Once the shade has been constructed, the nursery is ready to begin hosting new tree seedlings!

Constructing a vegetable nursery

A vegetable nursery is very similar to a tree nursery except that it is smaller. **Vegetable nurseries** work the same as tree nurseries by blocking sunlight, retaining moisture, and regulating the temperature around the seedlings.

A vegetable nursery is different mainly because of its size. The vegetable nursery should be constructed using poles that are only about a metre high. They should be spaces about 50 centimetres apart and should be buried in

holes about 20 centimetres deep. Once the frame has been constructed, it should be covered with enough grass to keep most of the sunlight off of the plants but still allow some sunlight through.

Vegetable nurseries are also different because they can be placed directly over the planting site. Rather than using poly-bags to help the seedlings grow, vegetables can be planted directly into the ground where the soil has been prepared. In a case such as this, the nursery should be built around the planting site, and removed when the vegetables are large enough to grow without the nursery shade. Sometimes, however, vegetables are grown in trays and then placed in the planting site. In this case, the nursery will be away from the planting area and it is important that the ground is flattened and hardened, just like the tree nursery.

Managing a Nursery

Once the tree and vegetable nurseries have been constructed, it is important that they are well managed. Much of this management process involves planting and caring for poly-bag seedlings, watering the plants, and eliminating pests. All of these topics will be covered in the following chapters. There are some other things that should be done to manage a nursery that are worth mentioning here.

A tree nursery with poly-bags waiting to be monitored

Firstly, it is important to make sure that the nursery shade does not collapse or break. If the shade falls over or collapses, it can break the delicate seedlings beneath. Therefore it is important that the structure of the shade is checked regularly and repaired when it is broken or weak. If the nursery does collapse and needs to be rebuilt, the poly-bags can be moved carefully to underneath a wide tree. The cover of the tree can provide some of the same benefits as the nursery and is a good substitute if the shade collapses.

Another important thing to do when managing a nursery is to **monitor** it for things like the development of seedlings, the presence of pests or infestations, and any other issues. Monitoring involves observing and keeping notes and records what is happening within the nursery. If plants are failing to grow, this should be recorded and investigated. Perhaps pests like rats or insects have gotten into the nursery and are eating the seeds. Perhaps a disease has infected the plants and the sick ones need to be removed. Or perhaps the nursery is not allowing enough sunlight to reach the plants. Whatever the problem, the only way to find out is to regularly monitor the nursery.

Monitoring also involves keeping track of how well the seedlings are developing. This may come in the form of a weekly log to track how tall the seedling or something along those lines. All records should be kept regularly so that they can be looked back upon and analysed to help make the garden as productive as possible.

Nurseries are incredibly important to the growth and development of agro-forestry gardens and they can help to make sure that the plants are healthy right from the start. In order to be successful, however, they must be built well and managed correctly.

Key Vocabulary:

- Soil moisture
- Temperature
- Frost
- Nursery
- Tree nursery
- Shade
- Vegetable nursery
- Monitoring

CHAPTER 15: Planting Agro-Forestry Plants

At this point in the guide, we have covered almost everything that must be done to prepare an agro-forestry garden. Now we will begin to look at some of the basic principles and practices that are involved in the actual managing of the garden. Now that we know how to find a location for a garden, secure a water source, clear the land, create a living fence, prepare natural fertilizers, and build nursery shades, it is time to begin planting the actual crops and trees that will be harvested for eating or selling.

We know from *Chapter 5* that that most plants follow the same process when growing. They begin life as a seed, which needs to be planted in the soil. After some time the seed will begin to grow, this tiny plant is known as a sprout. The sprout will grow up from the seed through the soil reaching for the sunlight. The sprout will also begin to grow tiny roots, which will grow down into the soil, searching for water and nutrients. Eventually, the sprout will grow into a seedling, which is basically just a small version of the mature plant. Finally, if the delicate seedling is well cared for, it will grow into an adult plant, which will produce more seeds, starting the cycle over again.

When reading this chapter, it is important to remember that each plant is different in how it grows and what it needs. Some plants grow much faster than others. Plants like trees may take many years to mature, while others, like vegetables can mature in less than a year. Similarly, some plants need lots of nutrients or water, while others can survive with less. This guide can only cover the general basics of planting and therefore, it is essential that further studying is done on the plants that are going to be grown in each garden so that the farmers know the specifics of those plants.

Preparing the soil for planting

There are two methods for planting trees and crops in an agro-forestry garden. Both methods were mentioned in *Chapter 14*, although not directly. The first method is called **nursery planting** and it involves planting the seeds in poly-bags and caring for the seedlings in the nursery. This method is used for plants that need a lot of attention when they are young. Many plants are delicate when they are in the early stages of growth, so it is important that they get the care that they need, but this care often involves a lot of work and resources.

The second method, known as **direct planting** involves planting the seed of the plant directly in the ground at the planting site. Direct planting is used for plants that are tough and do not need a lot of care. Even when they are young, these plants are able to survive in the garden without the protection of a nursery. This method helps to conserve the resources that would otherwise be spent raising these plants in the nursery.

Whatever method is being used, nursery planting or direct planting, it is very important to prepare the soil well before putting any seeds in it. We know that plants need healthy fertile soil that has the right composition in order to grow. Therefore, we should do everything that we can to give them this type of soil when they are planted. This will increase their chances of survival.

The first step in preparing the soil for planting is to create the right **soil mixture**. As mentioned before, every plant has a different soil preference, and therefore, every plant will need a different soil mixture. To create the soil mixture, heavy soil, sand, compost, and manure should be combined and mixed together. These should be added in proportions so that the right mixture can be made. These proportions depend on what plant is being grown and it will vary from plant to plant.

The mixing of this soil should be done in a large enough quantity to fill both the planting site and the poly-bags with enough soil. Once the mixing has been completed, the soil can be put into both the poly bags and the planting site. When using the nursery planting method, it is crucial that the soil in the poly bag is the same as the soil in the final planting site. This way, when the seedling is moved out of the nursery, it can be placed in the new area without getting shocked by any new conditions.

Making sure the conditions are the same in the poly-bag and in the planting site goes beyond the soil mixture, however. Once the soil has been put in the bags and at the planting site, attention needs to be paid to the moisture and the level of fertilization. In order to make sure that the soil moisture is the same, a watering regime needs to be put in place. A **watering regime** is basically a schedule of when to water the soil and how much water to add. Each plant will have a different regime, but whatever it is, it is important that the same watering regime is used for the planting site and the poly-bags to make sure that the moisture is the same.

In order to ensure that the level of fertilization is the same, a fertilization regime needs to be followed. A **fertilization regime** is a schedule of when to fertilize the soil and how much fertilizer to add. In this case, the fertilization regime will make use of liquid fertilizer, which will be poured on the site and over the poly bags in the quantities determined by the regime specific to each plant. Again, each plant will have a different fertilization regime, but whatever it is, it needs to be the same for the planting site and the poly-bags.

It is also important to make sure that when manure or compost is added to the soil, that it is not active. In *Chapter 13* we discussed how decomposing material can actually kill a plant if it is added while it is still decomposing. This is especially true for plants that have just been moved out of a nursery into the final planting site. The roots of these plants are delicate and can become infected with bacteria if they are planted in soil that has compost or manure that is still actively decomposing.

Even if the direct planting method is being used, it is still very important that the soil is prepared correctly even though poly-bags are not being used.

Preparing seeds for planting

After the soil has been prepared correctly, the next step is to prepare the seeds of the plants. In order for seeds to grow, they need to germinate. **Germination** is the process by which a seed transforms into a sprout. If a seed does not germinate, it will not grow into a plant and we cannot use it. Therefore, we need to make sure that as many of our seeds germinate as possible.

Many plants produce seeds that can be planted right away in the soil and do not need to be pre-treated before they germinate. These seeds can simply be placed right in the ground or in a poly-bag and they will be able to grow. Other plants produce seeds that have a hard shell or tip that is meant to protect the seed on the inside. Even though this protection is good for seeds in the wild, we do not need to have it in our agro-forestry garden.

The seeds with hard shells or casings need to be pre-treated. **Pre-treating seeds** can be done in several ways and involves removing the shell or casing of a hard seed so that it can grow faster. Without pre-treatment, some seeds will fail to germinate or will take a very long time to do so.

There are four methods of pre-treating seeds. The first method is called mechanical pre-treatment. **Mechanical pre-treatment** involves using a tool such as clippers to cut off the tip of a seed. Clipping off the tip of the seed before planting it allows water to penetrate the seed more easily once it is planted. When the water penetrates the seed, it will cause the inside to swell to the point that the outer shell cracks and the seed can begin to germinate.

The second method is called cold water pre-treatment. **Cold water pre-treatment** involves soaking a seed in cold water for about 24 hours. This will soften the outer shell of the seed and allow it to germinate quicker once it is placed in the soil

The third method of pre-treatment is called **hot water pre-treatment** and it involves soaking a seed in boiling water. In order to do this, water should be brought to a boil in a pot and the seed(s) should be placed in the boiling water. The pot should be removed from the fire and set aside to cool with the seeds in it. The water and the seeds should cool off to the side for about 12 hours.

The last method of pre-treatment is called **peeling by hand** and it involves removing the outer shell of the seed with your fingers. This is used for moringa seeds and others and is a good way to get the entire shell off of the seed before it is planted.

Different seeds will require different pre-treatments and some seeds do not need any pre-treatment at all. These requirements should be studied before pre-treatment begins so that the right pre-treatment is given to each seed. Regardless of what method is used, however, it is important that every pre-treated seed is planted immediately after it has been pre-treated. This means that after the tip has been clipped, the seeds have been soaked for the right amount of time, or the shell has been removed by hand, the seeds should be planted in the ground or in the poly-bags immediately. Pre-treating a seed and failing to plant it immediately can harm the seed and prevent it from ever germinating.

Managing poly-bag seedlings

Now that the soil and the seeds have been prepared, it is time to learn how to plant the seeds and care for the seedlings. This section will deal with how to prepare poly-bags for planting.

As we know from *Chapter 14*, a nursery is only a temporary home for the plants in our agro-forestry garden. Once they have grown into seedlings, they need to be moved to the actual planting site so that they can grow into mature plants and eventually be harvested. Because of this, the plants need to be able to be moved easily without damaging the plant. Plants and trees in the wild never move. Once they start to grow, they remain in the same place until they die. This means that plants do not like to be moved. When plants are moved from one place to another, they sometimes break or dry up. Even if they are successfully planted in their new location they can die from shock.

Even though plants do not like being moved, we have no choice because we have to move them out of the nursery. Therefore, we use special techniques to protect the plants and make moving them easier on us and on them. To do this, we use poly-bags. **Poly-bags** are small plastic sacks that can be filled with soil and used as a temporary pot for the new plants. Poly-bags allow us to move plants because they help to protect the delicate sprouts and seedlings. The poly-bag allows us to pick up the entire plant and the soil it is growing in when we move it. This means that the delicate roots do not need to be uncovered and exposed to the sun. When they are in the soil, roots and plants are less likely to break during transport. This allows us to send plants home with children or bring them to other gardens without harming them.

There are many benefits to using poly bags aside from being able to move them. Firstly, they allow us to give each plant its own small amount of soil to begin its life in. In other words, when a seed is placed in a poly-bag, it does not need to worry about **competing** for things like nutrients or water with other plants. Secondly, the poly bag is good for holding water. Because the roots of sprouts and seedlings are so short, they can only get water from right near the surface. A poly-bag holds water well so that the new plants always have water nearby.

In order to prepare a poly-bag for a seed, several steps must be followed. The first step is to add the soil to the poly bag. We know from the first section of this chapter that the soil in the poly-bag must be the same as

the soil in the final planting site so it is important that we take care when adding this soil. Enough soil should be added so that 3 centimetres at the top of the poly-bag are left unfilled. This will give us enough room to add water and extra fertilizer if needed. The next step is to poke a series of small holes in the bottom half of the bag so that some water can drain out.

Once the poly-bags have been filled with soil, they need to be arranged in the nursery. The next step of the planting process is very important. Because we want to make sure that our seeds do not have to compete with other plants in their poly-bags, we need to make sure that no other plants are in the soil. When we add manure and compost to the soil mixture, sometimes we end up adding the seeds of other plants that the animals have eaten. If these seeds are left in the poly-bags, however, they can harm the ability of our seeds to grow.

To deal with this, we must set the poly-bags up in the nursery and water them for a minimum of two weeks before we add the seeds. The reason for this is that when we water the poly-bags in the nursery, we give any unwanted seeds a chance to sprout and come to the surface. After this period of time, we should be able to go through the poly-bags and pick out any of the unwanted plants that have begun to grow.

After all of the unwanted plants have been removed, we can finally plant our seeds. The size of the seed determines how deep it must be placed in the soil but no seed should be less than 2 centimetres deep. Remember, if any of the seeds need to be pre-treated, this should be done immediately before planting the seeds in the poly-bags.

Caring for young plants

After the seeds have been planted in the poly-bags or directly in the soil, they will begin to grow. There are several things that need to be done to make sure that these new plants develop into healthy seedlings. First, it is important to remember to water the plants regularly. As mentioned before, every plant should have a specific watering regime that explains when to water them. This will be discussed further in *Chapter 16*.

The period of time between the planting of the seed and the sprouting of the plant is called the **germination period**. The germination period is

different for each plant but there are four main periods. The early plants have a germination period of between 5 and 9 days. The next series of plants have a germination period of between 9 and 15 days. The next group of plants have a germination period of 15 to 21 days, and the slowest growing plants will have a germination period of between 21- 30 days.

Children watering newly germinated plants in a nursery

Once the plants have germinated, it is important to pay attention to how many survive. If a plant germinates and then survives for at least a week, it has become **established**. Establishment is important because plants that have become established are more likely to survive into maturity. Part of caring for young plants involves keeping records of how many plants germinated and how many of those became established. Sometimes seeds are eaten by pests before they can germinate, other times the sprout will become infected and die before it can become established, but whatever the reason, it should be recorded so these problems can be addressed.

The amount of time that a plant spends in the nursery depends on what type of plant it is. Some plants need to be kept in the nursery for up to six months, while others only need to be kept for a few weeks. The minimum nursery time, however, is four weeks. Before plants can be removed from the nursery, however, they must be hardened. **Hardening seedlings** is a process by which we prepare the plants to be moved by getting them used to hard conditions. To do this, we reduce the watering regime. Some plants need a hardening of only a week while others require two weeks of hardening. During this time, the seedling will become prepared for the hash conditions outside of the nursery.

Transplanting and replanting

Once the seedlings have been hardened, it is time to move them to the actual planting site. During their time in the nursery, the soil that these seedlings will be moved to should have been kept on the same watering regime and fertilization regime as the seedlings themselves. If this has been done correctly, then it is time to move the seedlings. The process of moving a seedling from the nursery to the planting site is called **transplanting**.

Traditionally, farmers have used ploughs and other tools to turn or **till** the soil before planting. The belief was that tilling the soil made it better for crops to grow. Unfortunately, tilling has may negative impacts on the soil and the environment. Tilling can kill many of the important organisms in the soil and destroy the soil structure. Tilling also loosens the soil and can cause it to be easily eroded by wind or water. Therefore, this programme practices **no till agriculture**. This means that when plants are ready to be placed in the soil that a plough or hoe will not be used to prepare the ground.

Instead, all that needs to be done is to dig a small hole in the ground, enough to plant the seedling in. The seedlings are brought from the nursery still in their poly-bags. Then, the poly-bag is peeled off. The seedling's roots should hold most of the soil from the poly-bag together so that the whole thing can be placed gently in the hole that has been made. It is important to make sure that the plant is placed upright so that it does not grow crooked. Soil should be filled around the plant so that it comes to the base of the stem. Once the plant has been transplanted, it should be watered thoroughly to help with the shock.

Some plants will survive the transplanting process and others will not. For those that do not survive, replanting must take place. **Replanting** is the process of planting a new seedling in the same area where one previously failed to survive. When plants do not survive transplanting, it is important to investigate why, and then replant the new seedling in its place.

Once these steps have been taken, the agro-forestry garden is well on its way to becoming a successful plot of land full of food, produce, wood, fodder, and opportunity.

Key Vocabulary:

- Nursery planting
- Direct planting
- Soil mixture
- Watering regime
- Fertilization regime
- Germination
- Pre-treating seeds
- Mechanical pre-treatment
- Cold water pre-treatment
- Hot water pre-treatment
- Peeling by hand
- Poly-bags
- Competition
- Germination period
- Establishment
- Hardening seedlings
- Transplanting
- Tilling
- No till agriculture
- Replanting

CHAPTER 16: Watering Plants

As we know from *Chapter 5*, all plants need water to survive. Water is essential for plants for many reasons. Water drawn up from the ground by the plant's roots carries with it the many nutrients that the plant needs to grow and survive. Plants take up water through a process called transpiration, whereby the water is transported all the way up the plant from the roots to the ends of the leaves where it is given off as water vapour. As water moves through the plant, it brings nourishment and helps to keep the plant rigid. As you may know, a plant with insufficient water is generally dry and weak. When a plant has enough water, it swells and is able to hold up its leaves and branches.

If we are not careful to water our plants correctly, then they will likely die and all of the work we have done unto this point will have been in vain. This chapter will discuss how to tell if the soil is moist enough or not. It will also discuss the various techniques for watering plants. Again, every plant requires a different amount of care. Therefore, some plants need more water than others. It is important that this is checked before a watering regime is settled on.

Maintaining good soil moisture

Even though every plant has a different water requirement, there are some general techniques, which can be used to make sure that the soil that is being used is moist enough. We know from *Chapter 6* that **soil moisture** is a measure of the water content of the soil. Different soils respond differently to water and will have different moistures after water has been added.

Generally, however, soil content can be measured by a simple technique. To test to see if the soil has the right moisture content, first a small soil sample should be taken from about 15 to 20 centimetres underneath the surface. This should be done near the plant but care must be taken not to harm the plant. Make sure not to do this right after watering the plant. Instead wait a few hours or even a few days.

Next, you should take a handful of this soil and close your hand around it forming a fist. When you release your fist and hold the soil in the palm of your hand, some of the soil should have formed into clumps or balls and the rest of it should have broken apart again. If this happens, then the soil has a good

moisture content. If when you release your fist and see that all of the soil has formed into one long clump, then the soil is probably too moist. On the other side, if the soil forms no clumps at all and is dusty and dry, then it is probably not moist enough.

Of course, this method can only give you a basic concept of how moist the soil is and is by no means a perfect technique. As mentioned before, some plants may prefer a dryer or wetter soil. If the correct **watering regime**, or watering schedule, is followed for the specific plant, then this technique does not necessarily need to be used. The watering regime is created so that enough water is applied to keep the plant healthy and the soil moist enough. Therefore, following the specified regimes will help to maintain a good soil moisture.

One of the many issues that farmers have with soil moisture is waterlogging. We know from *Chapter 6* that **waterlogging** occurs when so much water is added to the soil that it cannot drain and the plants growing there basically suffocate. This is a problem in areas with heavy clay layers underneath the garden because clay can prevent water from draining. Therefore, it is important to know what type of soil is present so that waterlogging can be avoided by adding less water.

Irrigation methods:

We know from *Chapter 11* that **irrigation** is the process of diverting or adding water to a field or garden for the purpose of watering plants. Irrigation is vital for any farm or garden and there are several different techniques that can be used to irrigate crops. This section will look at some of the available methods and discuss their benefits and drawbacks.

The most basic and common method of irrigation is called bucket irrigation. **Bucket irrigation** involves filling buckets with water from whatever water source is being used be the garden, and then pouring that water directly over the plants. This method is fast and easy and does not require a lot of materials. Therefore it is recommended for new gardens that may not have access to other methods of irrigation. One drawback of bucket irrigation is that it is difficult to be exact with the amount of water that is needed. Nevertheless, this is a good and simple method for irrigation.

The next method is called sprinkler irrigation. **Sprinkler irrigation** uses pressurized water that is run through a hose and pushed through a sprinkler head where it is then sprayed all over the field. Many large farms across the world use sprinkler irrigation because it can cover a large area of land and involves very little labour. This agro-forestry programme does not use sprinkler irrigation for many reasons. First, sprinkler systems are expensive and require pressurized water. Second, because water is being sprayed everywhere, a lot of that water is wasted as it falls on ground that does not have any plants on it. Finally, sprinkler irrigation can actually destroy the soil. When the droplets of water hit the soil, they do so with a certain amount of force. If done for long enough, sprinkler irrigation can cause the soil to become compacted.

The next method for irrigation is called flood irrigation. **Flood irrigation** involves diverting a river or stream or some other body of water and allowing it to flood the entire field. This method is good for crops that need lots of water like bananas or rice and is used in many places around the world. Unfortunately, flood irrigation is perhaps the most wasteful form of irrigation because so much water is used. Flood irrigation can also only be done near a river or lake, which limits is usability.

The final method of irrigation, and the one that is most recommended by this guide is called drip irrigation. **Drip irrigation** is the least wasteful and most effective way to irrigate crops. It also involves very little work and once the whole system has been put in place it is very easy. The drip irrigation system uses gravity to bring water from a bucket directly to plants through a series of tubes. To make a drip irrigation system, several materials are needed. First, a metal stand about a metre tall must be acquired. Second a large bucket or drum with a tap at the bottom is needed. Finally, enough tubes and pipes are needed to run through the field and reach all of the plants that need watering.

The stand should be set up on a high point in the field. This is so the water can run downhill. Then, the large bucket or drum should be situated on top of the stand. Where the tap comes out of the bottom of the bucket/drum, a pipe should be attached. This tap should have a spigot where the flow of water can be controlled. At the end of the pipe, the drip tubes should be attached. These drip tubes should be run though the field along the rows of plants. Wherever a plant is growing, a hole should be poked in the drip tube.

A drip irrigation system showing stand, bucket, pipes, and drip tubes running through the field.

When the bucket is filled with water and the spigot is turned on, water will flow out of the bucked and into the drip tubes. The water will dribble out directly at the base of the plant, right where it is needed. When enough water has been let out, the spigot can be turned off and the whole system can be moved to another part of the field. Drip irrigation involves almost no work and is excellent for conserving water.

Drip irrigation is ideal for any agro-forestry garden because it is a sustainable way to use water for plants. But whatever the method that is used, it is important to make sure that the correct watering regime is used and that problems like waterlogging are avoided. If irrigation is done correctly, the garden will be more likely to produce healthy plants.

Key Vocabulary:

- Soil moisture
- Watering regime
- Waterlogging
- Irrigation
- Bucket irrigation
- Sprinkler irrigation
- Flood irrigation
- Drip irrigation

CHAPTER 17: Crop Rotation and Intercropping

So far we have covered the basics about starting an agro-forestry garden. As we discussed in *Chapter 10*, we know that agro-forestry is a sustainable alternative to traditional agriculture. Until now, however, we have not covered any of the techniques that set agro-forestry apart from any other farm operation. This chapter will focus on two of the major themes within agro-forestry: crop rotation and intercropping. Both of these practices are central to agro-forestry and contribute to the sustainability of the programme. This chapter will discuss the theory behind these two practices and briefly outline how they can be implemented.

Crop rotation

We know from *Chapter 5* that nutrients are central to plant growth. Most of the nutrients that plants need are found in the soil and are taken up by the plant's roots. Every time a plant or crop grows in an area, it decreases the amount of nutrients available in the soil. Naturally, the nutrients will return to the soil in a process called **soil replenishment**. If a crop is grown in the same spot year after year, the nutrients that the plant needs will become less and less abundant. Each time the crop is planted, it uses up the same nutrients, often faster than they can be replenished.

Eventually, the crop will no longer be able to find the right nutrients in the soil. This is called **nutrient depletion** and it is the process by which certain nutrients are removed from the soil by the repeated planting of the same crop. Nutrient depletion also occurs because each type of plant generally has the same root structure. The **feeding capacity** of a plant refers to the spatial ability of that plant to reach nutrients. In other words, plants that have long deep root systems will have a feeding capacity that is limited to a narrow column of soil. Conversely, plants with shallow, spreading roots will have a feeding capacity that is limited to a wide shallow area near the surface. Planting the same crop over and over again means that each new crop will be taking nutrients from the same place in the soil, leading to the depletion of nutrients in that area.

One way to fight nutrient depletion is to add fertilizer to soil to help replenish it. Unfortunately, this often leads to over fertilization and is not a very sustainable use of resources. Instead, it is best to practice crop rotation. **Crop rotation** is a system of alternating the type of crop that is being planted in

a particular area in a given year. For example, instead of planting cabbage four times in one year, four different crops would be planted in that same time span. Practicing crop rotation helps to fight nutrient depletion for two major reasons. First, because different crops are being planted, they will require different nutrients. This means that after a crop has been harvested, a different one will be planted that requires different nutrients, allowing the nutrients needed by the previous plant to regenerate in the soil. Second, even if the plants require some of the same nutrients, they will have different feeding capacities, meaning that they will be taking those nutrients from different areas in the soil.

Crop rotation is mainly used for growing vegetables because they grow quickly and are harvested often. The system suggested by this programme is a four vegetable cycle. The first set of vegetables is the leguminous plants such as pigeon peas. Once those have been harvested, the next set of vegetables are the bulb plants such as onions or leeks. After harvesting those, the next set are the cabbage plants such as cabbage, broccoli, or cauliflower. Finally, the cycle concludes with the planting of fruit bearing plants such as tomatoes. Following this cycle allows nutrients to be replenished in the soil as the crops are rotated in and out. It not only helps preserve specific nutrients, but it also saves some areas of the soil from being depleted. Similarly, planting leguminous plants can actually help to increase the amount of nitrates in the soil, which will benefit the other three crops as well.

Intercropping

Another major practice within agro-forestry is called intercropping. **Intercropping** is the process by which several plants are planted in the same area at the same time. Agro-forestry itself is based on the larger idea of mixing crops together with other plants. We know that many plants are excellent for things like creating barriers, fixing nitrogen, and providing fodder and firewood. While these are not necessarily considered to be traditional farm plants, they can be grown together with the other plants in the garden and used to provide many benefits. Mixing trees with crops is where the name agro-forestry comes from and it is essentially just a large example of intercropping. In fact, a good agro-forestry garden is essentially a huge intercropping experiment. Intercropping can also be done on a smaller scale within the garden by mixing different farm crops and plants.

When we grow one crop in an area, that crop is taking nutrients from one area in the soil based on its feeding capacity. This means that nutrients in other areas of the soil are not being used. Intercropping plants with different feeding capacities can help to make the most of the nutrients in the soil. This is called **maximizing nutrient usage** and it basically means that as many of the nutrients as possible in a given area are being put towards the crops, thus reducing the amount of wasted nutrients.

Intercropping can also help to **maximize resources**. One thing that intercropping does is conserve space in the garden because more plants are being grown in the same area. Intercropping can also maximize resources like water, because the water can be used for two plants rather than one. In other words, water that is not used by one plant can be used by the other.

While intercropping can help to make the most of nutrients and resources, it must be done carefully. Planting two plants in the same area can have some potential pitfalls when it comes to competition. First, the plant morphology and growth rates need to be paid attention to. For example, if a plant that grows fast and large is planted with a plant that grows slowly, the first will use all of the sunlight and cause the other to become shaded out. The intercropped plans should have similar growth rates so this can be avoided. Intercropping can also lead to nutrient depletion if not done correctly. Even though we want the soil nutrients not to be wasted, we must also make sure that in our effort to maximize the utilization of these nutrients that we don't deplete them.

Other Benefits of these Practices

Crop rotation and intercropping can also have a few other benefits aside from managing nutrients and resources. Firstly, growing several crops in a season leads to diversification. **Diversification** means that a farmer has many crops to sell in the course of one season. This gives that farmer more options in terms of selling produce. Diversification makes a farmer less vulnerable to the market. If a particular crop is not selling, the farmer has the option to sell another crop from a previous harvest. Similarly, if one of the crops fails that season, if the farmer is intercropping there should be other crops that did not fail.

Having a diversified garden can also help to improve the diet of that farmer and can provide a more balanced and nutritious set of foods. We know

from *Chapter 9* that nutrition is very important for human health. Having a variety of crops and plants growing in the garden gives families access to more nutrients. Eating only one crop is not enough to provide the nutrition that a person needs in order to live a healthy and active life.

These two practices can also help with **pest control**, which will be covered more thoroughly in *Chapter 18*. If a pest infests one of the plants in the garden, it may jump to the next plant if they are close enough. If the plant is intercropped with another plant, however, then it is more difficult for the pest to travel because there is a physical barrier created by the other plant. Pests are also less of a threat if crops are being rotated. If a pest depends on one crop to survive and reproduce, then only growing that crop once per cycle, rather than four times in a row, will disrupt this reliance and the pests will be less likely to survive. If crops are not rotated, then the pests can continue to feed on the same crop each time it is replanted. But if the crops are cycled through, then the pest will have no food for the rest of the cycle, which will help to reduce the total number of pests.

Key Vocabulary:

- Soil replenishment
- Nutrient depletion
- Crop rotation
- Diversification
- Feeding capacity
- Intercropping
- Maximizing nutrient usage
- Maximizing resources
- Diversification
- Pest control

CHAPTER 18: Weed and Pest Control

Two of the largest problems that farmers face are weeds and pests. Weeds and pests can be very dangerous to a garden and can cause severe damage to the crops growing within. A **weed** is a plant growing where it is not wanted and in competition with the crops that are being cultivated. Weeds are often fast growing and durable plants. They reproduce quickly and establish easily. They are good at growing back when they are cut down and they can often get out of control in a garden, causing harm to the crops because they outcompete them for resources.

A **pest** is a destructive insect or other animal that can harm or kill the plants in the garden. Insects such as termites and aphids are problematic because they feed on the plants in the garden. Pests can also be larger animals, however, such as pigs, goats, and cattle. Not only do these larger pests eat the leaves, fruits, and vegetables growing in the garden, but they can also trample the plants and kill them.

One method for controlling weeds and pests is to apply chemicals. Chemicals used to kill unwanted weeds are called **herbicides**. Herbicides are generally sprayed on fields to control weeds that have grown in. Although this method is easy, herbicides are not good for the environment. First, the chemicals in herbicides can kill plants that are not weeds. They can also kill any animals that might be feeding on the plants. Second, herbicides can contribute to chemical pollution and can contaminate our water sources when it rains. They can also contaminate the soil. Third, herbicides are generally expensive and not worth the cost, especially considering the environmental damage that they can cause.

Chemicals that are used to kill pests are called **pesticides**. Pesticides are also sprayed over fields to kill any of the insects that are living there. Like herbicides, pesticides are not good for the environment. They too can contribute to chemical pollution and can contaminate water sources and the soil in the garden. Pesticides are also dangerous because they tend to kill off all of the insects in the garden. This is not good because some insects are beneficial for the garden. For example, pesticides can kill bees that are needed to pollinate the crops. Pesticides are also very expensive and not worth the cost.

Weed control techniques

Instead of using chemical herbicides to remove weeds, this programme suggests a more environmentally friendly approach to weed control. We know from *Chapter 11* that part of preparing an agro-forestry garden involves uprooting all of the plants that are not wanted using hands or tools like spades and handpicks. **Uprooting** is a very effective method for eliminating unwanted plants because it takes the entire plant out of the soil including the roots. This prevents the plant from being able to grow back. Even after the initial land clearing process, uprooting weeds should be a regular activity in the garden. Whenever a weed is spotted, it should be uprooted and thrown away from the garden so that it cannot reproduce.

We also know from *Chapter 15* that sometimes our manure and compost can have the seeds of weeds that we do not want. We know that the best way to get rid of these weeds is to water the poly-bags so that the weeds sprout, after which they can be removed. This can also be done in the actual planting site as well.

Another method for preventing weeds is to use cover crops. **Cover crops** are crops that grow low to the ground and have broad or thick leaves that completely shade the ground beneath them. Because the ground beneath the crops is shaded and does not receive any sunlight, weeds will have a hard time sprouting. Some good cover crops are pumpkins, cucumbers, cowpeas, common beans, and melons. Cover crops can be integrated into the crop rotation and intercropping schemes covered in *Chapter 17* and they fit nicely into the overall goals of the agro-forestry garden because they are sustainable and do not leave any chemical residues like herbicides.

The basic goal of weed control is to make it harder for weeds to outcompete the plants within the garden. Regular weeding is important because if weeds are uprooted early, they are less likely to have produced as many seeds and therefore there will be fewer weeds in the future.

Pest control techniques

As we now know, pesticides are expensive and dangerous for the environment. Rather than polluting the garden with these chemicals, other more natural methods should be used to control for pests.

One of the best ways to kill pests without using chemicals is to make use of natural predators. **Natural predators** are local animals that naturally feed on pests. For example, owls and other birds eat many insects and some even eat rats. Having these birds around to act as natural predators can help to keep pests down. Another example of a natural predator is the preying mantis, which hides under the leaves of plants and feeds on the aphids that attack the plants.

One benefit of agro-forestry is that the trees that are incorporated into the garden make a good habitat for natural predators like birds. Having birds like owls around can help to control pests without having to do any extra work. Another downside to the use of chemical pesticides and herbicides is that they can poison natural predators like birds and preying mantis. When these natural predators are killed off, the pests will come back even stronger the next year.

Another simple method for getting rid of pests is to do hand scouting. **Hand scouting** is basically just the process of removing pests by hand. This is similar to weeding in that every time a pest, such as a beetle or slug is seen on a crop, it should be removed immediately. This is a very easy process and can be done everyday in the garden.

There are two other methods for controlling pests that are very effective. The first is to use plant extracts. Some **plant extracts** like those that come from gliricidia and tephrosia are poisonous to many pests. Spraying these natural plant extracts on the garden can control termites, underground pests, and other leaf-eating pests. Because these are natural products, they leave no chemical residues and do not pollute the environment. The other method is to use scent repellents. **Scent repellents** are smells that keep certain pests away. The smell of neem seeds and lemon grass for example are very strong and repel pests. These plants can be grown in the garden and provide a natural form of protection from pests that can harm the crops without causing any environmental harm.

Key Vocabulary:

- Weed
- Pest
- Herbicides
- Pesticides
- Uprooting
- Cover crops
- Natural predators
- Hand scouting
- Plant extracts
- Scent repellents

CHAPTER 19: Harvesting, Processing, and Storing

Harvesting Principles

Once a garden has successfully been established it should begin to yield the items that will be eaten, sold, or used in another fashion. **Harvesting** is the process of collecting the produce from crops and other plants. Depending on what is being harvested, different processes will be used. Nevertheless, there are some general pitfalls that must be avoided when harvesting and processing a crop. Essentially what we want to do is to get the most out of our garden each time we harvest. This means **maximizing yields** so that all of the product is stored, sold, eaten, or used in some other way and as little of it as possible goes to waste.

The first thing to remember when harvesting is timing. Care must be taken to avoid **premature harvesting**, which is when produce is harvested before it is ripe or ready. This is a problem because produce that is harvested prematurely has not fully developed and will be useless for selling or eating. On the other hand, if you wait too long to harvest, some of the produce may have rotted or become too dry to use. It is important to understand how to recognize when a plant is ready to be harvested so that these issues can be avoided.

The next thing to pay attention to when harvesting is how much is being harvested. **Overharvesting** a plant happens when more produce is harvested than can be used or sold. Once items such as fruits are harvested, they begin to decay and dry up. Therefore, if not all of the harvested produce is sold or eaten, the unused items will go to waste. Understanding the **demand**, or the desire of purchasers or users for a product, can help to avoid overharvesting.

Once a product has been harvested, it needs to be processed. **Processing** is basically preparing the produce in one of many ways to be sold, eaten, or used. There are many ways to process items from a garden. Some products, like firewood from gliricidia, are processed by stripping the leaves from the plant. Other products, like seeds, are processed by being removed from the plant and stored. Some products are dried to preserve them and others are simply sold or eaten right away.

Regardless of what processing technique is being used, care must be taken to hand the products correctly. Careful **handling** is important so that we

do not ruin any products when we are processing them. This will help to maximize yields from the garden and will reduce the amount of wasted products. This way we will have as much produce as possible to sell, eat, or use.

Preservation and solar dried products

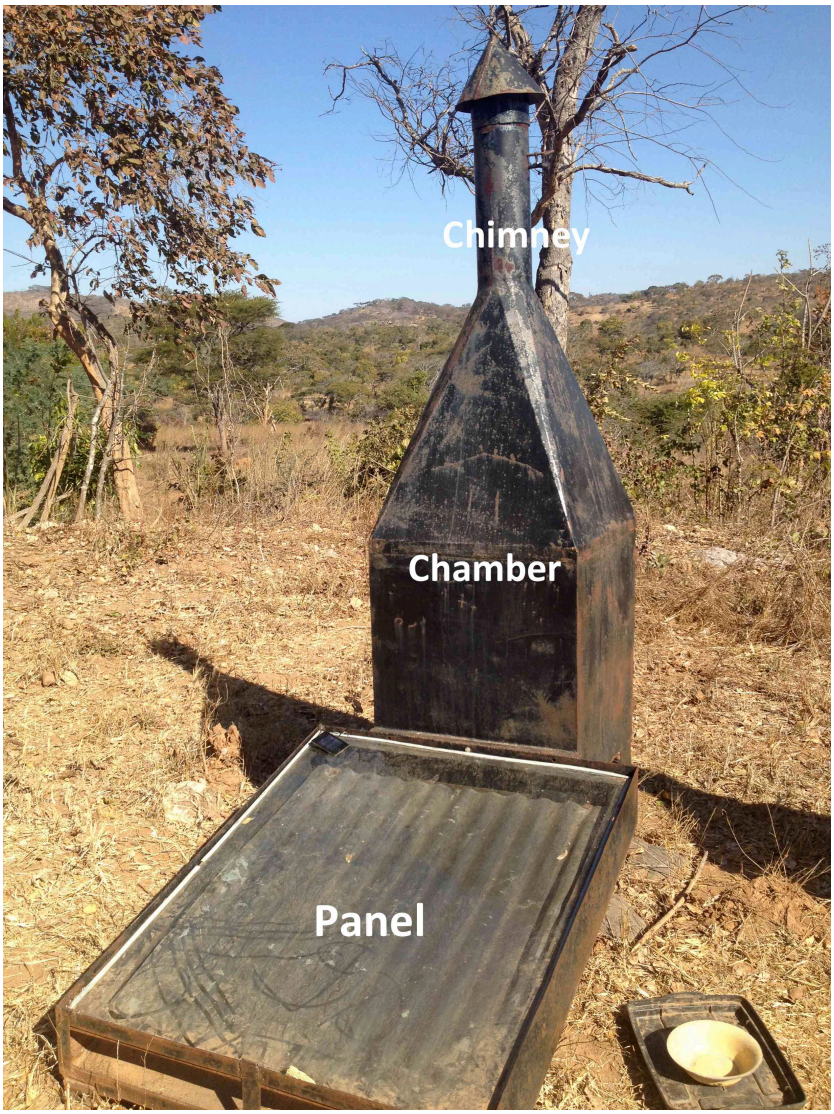
One of the ways in which products are processed is to preserve them. **Preservation** is the act of maintaining a product after it has been harvested so that it can be used, sold, or eaten at a later time. Some products like fruits and vegetables do not need to be preserved because there is usually demand for fresh produce such as these. Therefore it can be sold or eaten without needing to be maintained for long. Many products, including fruits and vegetables however, need to be maintained and preserved so that they can be transported, sold at a later time, or stored.

Preservation is very important in places like Zambia where food is sometimes hard to find in the dry season. If products from an agro-forestry garden are preserved, they can be eaten or sold during the dry season when they would otherwise not be available. This helps to increase **food security**, or the ability to find enough nutritious food to eat. It also helps to create **income generating opportunities** for people because they are able to sell products long after they have been harvested. If a product is preserved, it is more secure in the market as well because its price is not influenced by market conditions. For example, if a farmer has a lot of produce that is going to go bad soon, he may have to lower his prices in order to sell it before it is ruined and can't be sold at all. If his products are preserved, however, then he does not have to worry about lowering the price and can simply wait until people buy the product.

There are many ways to preserve products including freezing them or using chemicals or preservatives. Because these methods are not readily available to smallholder farmers, the best alternative is to dry the products. Drying products is one method for preservation that does not require much effort or materials.

The best way to dry products is to use a solar dryer. **Solar dryers** capture the heat from the sun and channel it up into a chamber where it acts as an oven and can be used to dry agro-forestry products. Solar dryers have three main components: the panel, the chamber, and the chimney. The panel is a flat

box with a sheet of rippled metal inside, which is painted black. The surface of the panel is a glass sheet. At the base and top of the panel are slight openings where the air flows. The chamber is placed behind the panel and is filled with several racks of wire mesh inside of it. These racks are where the produce that is being dried is placed. There is a door at the back of the chamber, which gives access to the racks. Finally, the chimney rises out of the chamber and allows the hot air to pass through.



The front of a solar dryer outside of an agro-forestry garden showing the panel, chamber, and chimney.

When the sunlight hits the panel, it heats up the air underneath the glass, As this air is heated, cool air is drawn in from the base of the panel, which then forces the hot air up the panel and into the chamber. Because the chamber is sealed everywhere except the top, the hot air heats the inside of

the chamber like an oven causing the produce inside to dry. The hot air continues up and out the chimney as more hot air is drawn in from the bottom. The process of cycling hot air through a system such as this is called convection. Solar dryers like the one above have the ability to dry about 3 kilograms of produce a month.

There are many products, which can be preserved by drying them in a solar dryer. Solar drying can preserve everything from cucumbers, black jack, cassava, mushrooms, onions, sweet potatoes, pumpkins, tomatoes, moringa leaves, mangoes, bananas, and many other products. Almost any product can be put in a solar dryer and preserved.

The benefit to using a solar dryer as opposed to simply drying products in the open air is that the solar dryer is able to preserve the nutrients in the products. **Nutrient preservation** is very important because it means that even though the product is dry, it still has all of the nutritional value that it did before. We know from *Chapter 9* that having a balanced diet with plenty of nutrients can help to keep us healthy and give us the energy we need to be productive everyday. Solar drying agro-forestry products allows us to preserve foods so that we can eat them all year long and still be able to get the nutrients that we need. Solar drying is also beneficial because the chamber can be locked, securing the produce inside.

When using a solar dryer, it is important to remember to keep it safe. Solar dryers should be placed on stands high enough from the ground to prevent goats and other animals from jumping on them and breaking the glass or bending the panel. Making sure that the ripples sheet is always covered with black paint will help to make the solar dryer more efficient.

Seed and product storage

After processing, some products need to be stored. Again, **fresh produce**, such as guava, lemons, oranges, tomatoes and bananas, do not always need to be preserved or stored because there is usually enough demand for them to be sold or eaten right away. Things such as seeds, leaves, and fodder, on the other hand, do need to be stored. The benefit of storing products is that they can be kept safe while they are waiting to be used. If a garden has nowhere to store its products, they may end up being wasted. Having the ability to store products allows them to be protected until they are used, sold, or eaten.

One of the things that can help an agro-forestry garden is to construct a storeroom. A **storeroom** is a place that is protected from the heat, rain, and wind and can be used to keep preserved items safe. A storeroom does not need to be large but it should be sturdy and secure to keep the products inside safe.

Seeds are one of the most important products that can come out of an agro-forestry garden. Not only can many seeds be eaten or used to make things like oil, but they are also necessary for planting the next round of whatever plant they come from. Regardless of whether seeds are harvested from the garden, collected from the bush, or sourced from organizations like Taonga or the National Irrigation Research Station, seeds should be stored and kept safe. Glass or plastic bottles, plastic container and plastic bags are excellent for seed storage. These containers help to prevent air, pests, and moisture from getting to the seeds and ruining them. Seeds should be kept in a cool dry place such as a storeroom.

Products like leaves that will be used for animal fodder or for human use should also be stored in a similar way once they have been dried. Some of the products need to be further processed once they have been dried. Moringa leaves, for example, need to be crushed into a powder and put into containers or bags so that they can later be sold.

Key Vocabulary:

- Harvesting
- Maximizing yields
- Premature harvesting
- Processing
- Overharvesting
- Demand
- Handling
- Preservation
- Food security
- Income generating opportunity
- Solar dryer
- Convection
- Nutrient preservation
- Fresh produce
- Storeroom

CHAPTER 20: Marketing Products & Generating Income

The final step for any agro-forestry garden is to get the products from the garden to the end user. The **end user** is the person or persons who will be eating or using the final products from our gardens. Sometimes, the end users are the people working at the agro-forestry garden. Part of the reason why agro-forestry should be adopted is because it can help the people who practice its techniques. Not only do these people save money and resources, but they also have a more secure food source and the potential to generate income by selling their products.

Different agro-forestry products

Agro-forestry gardens have the potential to create many different products, which can be sold for a profit. Before we discuss how to get people to buy these products, it is worth covering the various different products that can come from an agro-forestry garden.

The first and most obvious product that comes from a garden is food. **Food products** are the primary item produced in a garden and are sold to people so they can eat them. There are many food products that can come from a garden such as cereals, legumes (beans and peas), fruits (bananas, lemons, guavas, mangoes), vegetables (cabbage, onions, tomatoes, carrots), and many others. These products are what we harvest from the crops. Many of these are taken home and eaten by the farmers while some are sold or dried.

The next set of products that can come from an agro-forestry garden are material products. **Material products** are things that are not eaten but rather used for another purpose. A good example of this is timber. We know that gliricidia can be chopped down and used for firewood. It is also a good building material because the wood is so strong and it grows very straight. Other plants can be used to make fibres, which can be turned into rope. Another example of a material product is Jatropha seeds, which can be turned into oil. We know from *Chapter 18* that some plant extracts can be used as pest repellents. These same extracts can be sold as material products.

There are also many less obvious products that can come from an agro-forestry garden. These are called **indirect products** because they are not

intended to be part of the garden and are not planted but they can still be used or sold. Some of the trees that are left in the gardens can produce wild fruits or seeds that can be sold or eaten. Another example of an indirect product is honey. Because the trees of agro-forestry gardens provide a good habitat for bees, the honey that the bees produce can later be harvested and sold. Similarly, the shade and moisture that these trees provide allows things like mushrooms to grow. These mushrooms are an indirect product and can also be harvested and sold.

Another product produced by agro-forestry gardens is animal food or **fodder**. Many of the trees that can be used in agro-forestry gardens produce leaves or peas that are very healthy for animals. Fodder is an important product that comes from agro-forestry gardens.

Finally, agro-forestry gardens can help to produce animal products. **Animal products** are things that come directly from animals such as milk, meat, butter, eggs, and even leather. Because agro-forestry gardens have many nutritious plants that can be fed to animals, these animals are often raised near the garden. These animals are healthier as a result of eating agro-forestry products and therefore they will have better milk, eggs, and meat. When animals are raised in coordination with an agro-forestry garden, they can provide an entirely different set of products that can be sold.

Marketing strategies

Now that we have covered the different types of agro-forestry products, we can discuss how to sell them and generate income. In order to generate income, however, buyers must be found. The process of convincing buyers to purchase a product is called **marketing**. Marketing involves finding a way to promote a product so that people feel the need or the desire to buy it. People must value a product in order to be convinced to buy it. When a person values something, they have an incentive to buy it. An **incentive** is what motivates people to buy something and it represents the benefit that a person will receive when they buy the product. Marketing involves showing people that there is an incentive to buy a product.

One of the strongest marketing strategies for this agro-forestry programme is social marketing. **Social marketing** is a strategy that gives people a reason to buy a product based on the social benefit that they will contribute by doing so. Because the agro-forestry gardens described in this programme

are based at schools, the profits that they earn will go back to the school and will benefit the children. If someone knows that buying a product from a Taonga agro-forestry garden will help to fund the education of children in the area, they will be more compelled to buy it. Social marketing is especially powerful in developed countries where people are looking for an easy way to help those in need. When promoting a product, the social benefits should be made clear to the buyer.

Another useful marketing strategy is health marketing. **Health marketing** is a strategy that gives people a reason to buy a product based on the health benefits they will receive when they consume the products. We know that many of the products grown in the agro-forestry garden are extremely good for people. When people are aware that eating a balanced and healthy diet can help them feel better and be more productive, they will want to find products that are healthy. People who can clearly see that buying agro-forestry products can benefit their health, they will be more likely to buy it. When promoting a product, the health benefits should be made very clear to the buyer.

Having the health benefits of moringa leaf powder printed on the top of the container is an example of health marketing.

Another very powerful method for convincing people to buy products is environmental marketing. **Environmental marketing** is a strategy that gives people a reason to buy a product based on the environmental benefits that buying that product has. Practically this whole guide has focused on why agro-forestry is a sustainable alternative to traditional agriculture. Agro-forestry conserves water, protects trees, reduces erosion, and does not pollute the earth. Protecting the environment is something that all humans should care about because we are all a part of the environment and we depend on it for our survival. People who understand this will be more willing to buy products that support sustainable initiatives such as this programme because they know that by buying these products, they are helping the environment. The environmental benefits of agro-forestry products should be made as clear as possible when promoting them.

The simplest form of marketing is called financial marketing. **Financial marketing** is a strategy that gives people a reason to buy a product because it is cheaper than others or because it will save them money. If two farmers, one from an agro-forestry garden and the other from a traditional garden, are selling vegetables at a market, they will be competing and will want to attract buyers. Because the agro-forestry farmer did not have to buy fertilizer, pesticides, or herbicides, producing his crop was much cheaper than it was for the other farmer to produce the same crop. Therefore, he can offer a lower price and attract more customers. This is true for many agro-forestry products as well. Firewood cut from gliricidia trees will grow back quickly meaning the farmer does not have to go searching for new trees. Therefore he can sell more firewood and at a lower price. Financial marketing is a good way to promote products but lowering prices should only be done if profits can still be made.

These are some of the strategies that can be used to make an agro-forestry garden a sustainable and profitable operation for any farmer in Africa.

Key Vocabulary:

- End user
- Distribution
- Food products
- Material products
- Indirect products
- Fodder
- Animal products
- Marketing
- Incentive
- Social marketing
- Health marketing
- Environmental marketing
- Financial marketing

CHAPTER 21: Agro-Forestry Plants

There are many different plants that can be grown in an agro-forestry garden that can produce food, fertilize the soil, break the wind, and have many other benefits. This final chapter is devoted to giving a brief summary of some of the most important and useful plants that can be incorporated into the agro-forestry garden. Information is given on how to prepare the seeds, how long the germination period is, the watering regime, how long it takes before harvesting can begin, and some of the benefits and uses of the plants.

Moringa spp. (Drumstick):

Moringa is one of the best plants to grow in an agro-forestry garden because of its many benefits. Moringa is an excellent fertilizer tree, which can significantly improve the soil fertility in the garden. The leaves and litter from the tree are excellent for compost heaps. Moringa requires very little work once it has become established. Gram for gram, Moringa is one of the most nutritious supplements in the world. It is rich in iron, calcium, potassium, protein, vitamin A, vitamin C, and antioxidants making it an incredibly healthy crop. The leaves can be dried and crushed and sold as a powder, which has proven have a very large market potential, making it one of the best options for an income generating crop. Moringa is also a good option for intercropping with certain vegetables.

Seed Preparation: peeling by hand
Germination time: 9-15 days
Time to harvest: 8 months
Watering regime: Every 2 days while in nursery, should be transplanted at the onset of the rainy season so that it can survive on rain water until it is self-sufficient

Bidens pilosa (Black Jack):

Black Jack is another crop with many health benefits. It has been known to help with hypertension. Black Jack can also be used to help wounds heal faster. It is also been said to be capable of treating some kidney problems.

Black Jack can be dried or left fresh and can be made into a nutritious relish with many health benefits. Black Jack grows very quickly and is able to be harvested shortly after germination.

Seed preparation: None
Germination time: 7 days
Time to harvest: 7 days after germination
Watering regime: Daily until germination, then every 2-3 days

Cajanus cajan (Pigeon Peas):

Pigeon peas are one of the most versatile plants that can be grown in an agro-forestry garden. The beans that come from this plant can be used for both human consumption and for animal feeding. The beans are very nutritious and can help both humans and livestock get their needed nutrients. The plant produces beans for a long time, rather than all at once, so it can be harvested 3 or 4 times before it runs out. Pigeon peas are also a leguminous plant, making them an excellent nitrogen fixer. The leaf litter and biomass from pigeon peas are good for composting because they are rich in so many nutrients that other plants need. Pigeon peas can be left in the garden for two years and can help to prepare the soil for cereal crops because they generate so much nitrogen and biomass.

Seed preparation: None
Germination time: 7 days
Time to harvest: 3-6 months depending on rain
Watering regime: Everyday until germination, every 2 days after germination, self-sufficient after 3 months

Vigna unguiculata (Cowpeas):

Cowpeas are a deep-rooted plant that do not require a lot of watering after they have become established. Cowpeas are also a leguminous nitrogen fixer, which can increase soil fertility. Humans and animals can eat both the leaves and the peas. The peas are rich in protein, which make an excellent addition to any human or animal diet.

Seed preparation: None

Germination time: 5-7days
Time to harvest: 4 weeks for leaves, 6 weeks for peas and pods
Watering regime: Every 2 days until germination, every 3 days after that

Tephrosia (Fish Poison):

Tephrosia is a fertilizer shrub that helps to create fertile soil by dropping biodegradable leaf litter that builds biomass in the soil. The leaves can also be added to compost heaps to make rich soil mixtures. Tephrosia can also be made into a natural pest control product. The leaves of the plant are soaked in water and strained to extract the sap. 1 litre of leaf extract can be mixed with 3 litres of water to make a very potent pest repellent. Adding more water can reduce the strength of the repellent. The chaff from the straining can be added to compost heaps. The seeds of Tephrosia can be crushed in to a powder in which other seeds can be stored. The powder can help to protect the seeds from weevils.

Seed preparation: Cold water pre-treatment (optional)
Germination time: 7-9 days
Time to harvest: 6 months for seeds
Watering regime: Daily until germination, every 2 days after germination for two weeks, after one month it should be self sufficient

Leucaena spp.:

Leucaena trees are incredibly versatile. They are a good fertilizer tree and provide wind protection. The wood is useful for firewood as well as for light construction of things such as fences. Leucaena trees are also one of the best fodder plants available in any agro-forestry garden. The smallness of the leaves makes them a good fodder option but they can also be used in compost heaps. The leaves are rich in protein, which boosts the productivity of the animals that eat them. Fodder from these leaves can increase the production of milk and eggs in animals and is easily converted into healthy meat. The leaves can be used fresh or dry and can be included in other animal supplements.

Seed preparation: Cold or Hot water pre-treatment

Germination time: 7 to 9 days if treated, 21-30days if untreated
Time to harvest: 10 months
Watering regime: Everyday until germination, every two days after germination, self sufficient after 3 months because of deep roots

Gliricidia sepium (Quickstick):

Gliricidia offers a sustainable source of firewood and building materials. If planted close together, these hardwood trees will grow very straight, making good building material. Gliricidia trees will re-sprout and re-grow even when they are cut all the way to the ground, meaning that they can be used year after year for firewood. As they age, these plants produce more and more litter and wood. Gliricidia also provides good wind protection and a good firebreak because it prevents grass and other plants that burn easily from growing underneath. Lines of gliricidia can be used to make large firebreaks. This plant is also a nitrogen fixer and all of the leaf litter makes for excellent compost material. Gliricidia is also drought and termite resistant and as an adult it is temperature resistant too. Gliricidia also provides excellent habitat for bees.

Seed preparation: None
Germination time: 5 -9 days
Time to Harvest: 2 years
Watering Regime: Everyday until germination, every other day for a week after germination, then every 3 days, should be self-sufficient after 5 months

Sesbania spp.:

Sesbania trees are a fast growing plant that does not need to be raised in a nursery. They are a good fertilizer tree and also provide good wood for light construction. Although they do not produce a lot of leaves, they are a very nutritious fodder product. Sesbania can also be used medicinally to help fight urinary tract and bladder complications.

Seed preparation: Cold water pre-treatment
Germination time: 9 -15 days
Time to Harvest: 1 year

Watering regime: Everyday for first 3 weeks, self-sufficient after that

Faidherbia albida:

Faidherbia albida is one of the best fertilizer trees available for agro-forestry gardens. The leaves are rich in nitrogen and calcium, which can help replenish the soil when they fall. The seeds can be used for animal fodder and for replanting but take a while to be produced. This is one of the most widely adopted fertilizer tree varieties because it does not require much water or care and has very wide ranging benefits. After about 5 years, gardens can benefit immensely from these trees.

Seed preparation: Cold water, Hot water, or mechanical pre-treatment
Germination time: 12-21 days
Time to Harvest: 10 – 15 years for seeds
Watering regime: Daily before germination, every 3 days after germination, should be transplanted at the onset of the rainy season so that it can survive on rainwater until it is self-sufficient

Mexican apple:

Even though it takes several years to bear fruit, the fruit of Mexican apple trees is very sweet and delicious. These trees provide excellent shade and are a good windbreak. The wood is very strong and can be used for building, firewood, or for making handles for tools.

Seed preparation: None
Germination time: 21 – 30 days
Time to Harvest: 5-15 years
Watering Regime: Everyday for first week, every 2 days for second week, every 2 days for third week, should be transplanted at the onset of the rainy season so that it can survive on rainwater until it is self-sufficient

Jatropha curcas:

Jatropha is not necessarily a very useful crop, but it is one of the most important plants for creating a living fence. The plant establishes quickly and can be propagated easily. If a branch of Jatropha is cut and placed in a new area, it will grow into a new Jatropha tree. This plant responds well to chopping and can be managed as a hedge easily. The seeds of Jatropha can be turned into oil, which can be used to run some machines. The oil can also be used as lamp fuel with the ability to repel mosquitoes. This oil also produces fewer fumes than kerosene when used in lamps.

Seed preparation: None
Germination time: 7-15 days
Time to Harvest: 1 year, 6 months if propagated by cutting branches
Watering Regime: Everyday until germination, every 2 days for first two weeks after germination, every 3 days after third week, should be self-sufficient after 5 months.

Trichilia (Musikili):

Trichilia is a very useful wind breaking tree and provides good shelter for animals. It is also a beautiful ornamental tree that stays green all year long. It produces leaves, which can be used for fodder. After many years, the fruit of the tree can be eaten as well. This is a native plant.

Seed Preparation: Cold water pre-treatment, then scrub to remove coating
Germination time: 7 – 9 days
Time to Harvest: 25 years for fruit, 1 year for leaves
Watering Regime: Every 2 days until germination, continue for three weeks after germination, after three weeks, every 3 days, don't want to water too much or it will rot, should be transplanted at the onset of the rainy season so that it can survive on rainwater until it is self-sufficient

Tamarind (Musiika):

This is another native tree that is a useful windbreaker. Although it takes many years to produce fruit, older trees can produce up to 3,000 kilograms of fruit a year. The fruit is very rich in protein and Vitamin C. It can be turned into nutritious marmalades or juice. The fruit can be added to porridge or nshima as a protein supplement. These trees are also a great habitat for bees. The extract from the bark can be used to heal skin irritations and rashes.

Seed preparation: Hot water, Cold water, or Mechanical pre-treatment
Germination time: 15-21 days
Time to Harvest: 15 year for fruit if undisturbed
Watering Regime: Every day until germination, every 2 days for one week after germination, every 2-3 days after two weeks, too much water will cause it to rot, should be transplanted at the onset of the rainy season so that it can survive on rainwater until it is self-sufficient

Azaza (Mutobo):

Azaza is a native tree that produces excellent hard wood. This wood can be used for heavy or light construction or for making tool handles. It can also be used as firewood. This tree is also a good windbreaker.

Seed preparation: Mechanical pre-treatment
Germination time: 21-30 days,
Time to harvest: 2 years
Watering Regime: Every 2 days until two weeks after germination, then every 3 days after that, should be transplanted at the onset of the rainy season so that it can survive on rainwater until it is self-sufficient

Agave sisilana (Sisal):

Sisal is another excellent living fence addition because it has large spike shaped leaves that keep pests out. This plant is self-propagating so it doesn't need to be planted many times. Its leaves can be made into fibre and rope.

Juncia (Sun hemp) and Velvet beans:

Sun hemp and velvet beans are excellent plants for preparing soil for other plants because they will germinate in 3 to 5 days and they help to fix nitrogen and add calcium to the soil. Their biomass is very rich in nutrients and can be added to compost heaps. These plants are also useful cover crops and can keep weeds down.

Agro-forestry vegetables:

- African Cucumber (Makowa)
- Amaranth (Bboonko)
- Banana
- Cabbage
- Carrots
- Cassava (Mwanja)
- Cat's whisker (Luyuni)
- Cocorus (Bbuyu)
- Mango
- Moringa
- Mushroom (Bowa)
- Okra (Delele)
- Onion
- Parsley
- Pumpkin (Mungu)
- Pumpkin leaves (Chibwabwa)
- Rape
- Sweet Potatoes (Chimbwali)
- Sweet Potato leaves (Kalembula)
- Tomatoes (Madede)

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