
PERMAVILLE

The Permaville Handbook:
Strategies of Permaculture Design

Version II

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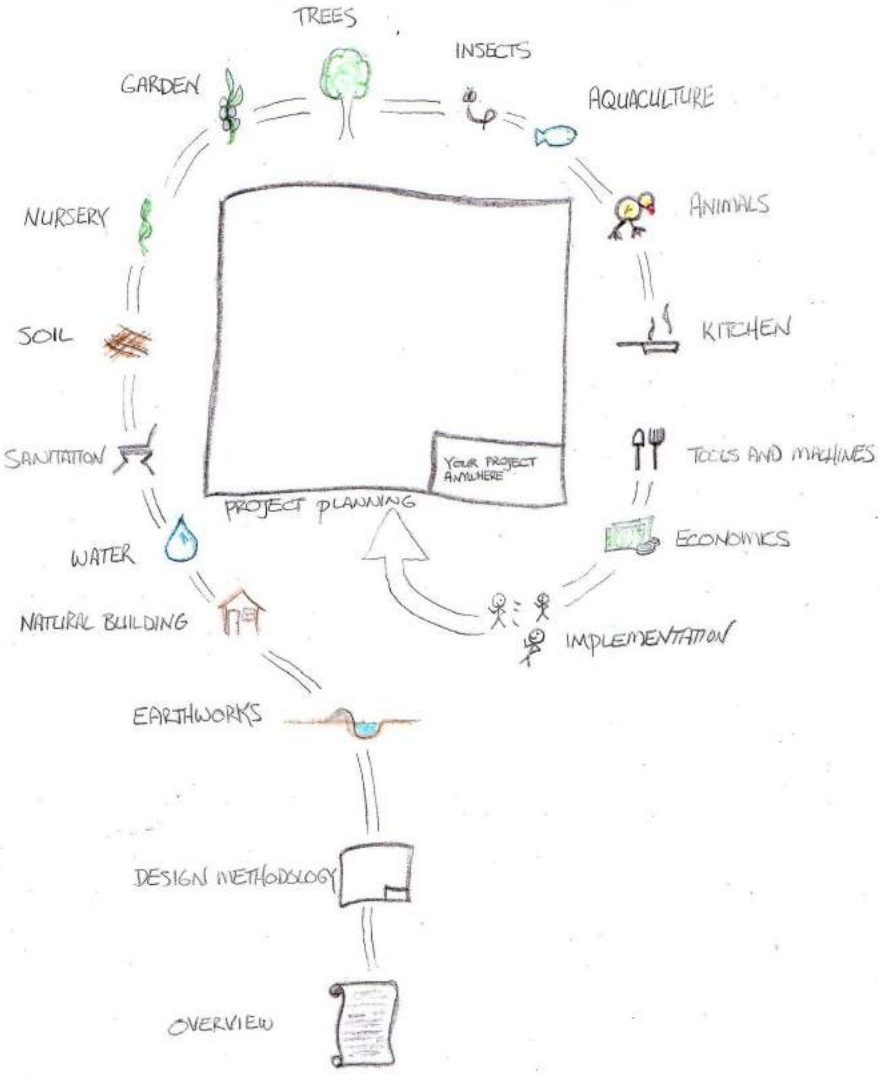
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Introduction

"Though the problems of the world are increasingly complex,
The solutions remain embarrassingly simple." — Bill Mollison

Permaculture is the study and practice of sustainable living. At its core, Permaculture is a method of living in harmony with the world around us, and creating abundance from it. Long before Bill Mollison and David Holmgren, the naturalist and academic considered the co-founders of permaculture, coined the term in the 1970s, people were living in communities guided by its principles, and adapting to a changing world as their ancestors had done for generations.

This handbook is a concise overview of the basic techniques, principles and values that are frequently taught in a Permaculture Design Course (PDC), a 72-hour class that provides an overview of the many aspects of holistic community. Thousands of people have taken part in such courses all over the world, several dozens in classes I facilitated in communities in Thailand, Laos, Nepal and India.

If you want to live more closely in tune with nature, to live a simpler life and to meet other folks who want the same, this book is an introduction. You will learn what permaculture is and how you can apply it to your life, in a short amount of time.

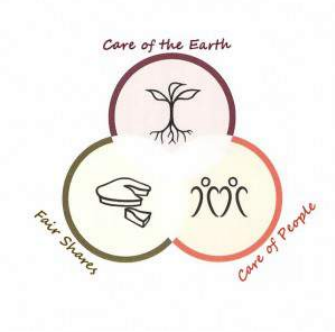
This book aims to provide an overview of permaculture's principles, teach some core permaculture techniques and practices, and provide direction and resources for connecting with people who share a passion for the work.

Overview

Permaculture Principles

The overall goal of permaculture is to be self-reliant by producing a surplus of food water and energy within a site. Here is a list of more specific goals as they relate to each chapter:

1) Earthworks - Capture rainwater and provide access to the site
2) Natural building – Provide housing for people and animals
3) Water – Clean, conserve and reuse water
4) Sanitation – Produce no waste
5) Soil – Build soil
6) Nursery – Propagate plants
7) Garden – Grow and harvest edible plants
8) Trees – Grow useful trees and food forests
9) Aquaculture – Raise healthy fish and plants
10) Insects – Raise beneficial insects and keep pests away
11) Animals – Raise healthy animals using the resources available
12) Kitchen – Prepare, ferment or preserve food grown on site
13) Tools and technology – Use energy efficiently
14) Economics – Create a surplus
15) Project planning – Install a permaculture design



Permaculture Ethics

1) People care – Be considerate of everyone's time, interests thoughts and actions, including your own.
2) Earth care – Care for the earth, animals, plants, trees, fungi, micro-organisms, water and air and everything else.
3) Fair share – Fairly distribute surplus among humans as well as with nature, if there is any.

Permaculture Design Approach

Permaculture design is the process of designing and maintaining a long-term permaculture plan. Permaculture communities can take years to mature, and having a defined and adaptable design process is important to their long-term success. At it's most basic, the design process is a plan for creating a permaculture community that matches its capabilities with its goals.

Analyze resources -- Set goals -- Design – Implement – Evaluate -- Repeat

This design approach is the same for both large permaculture site designs, and individual projects such as a composting toilet or plant nursery. Whatever project you are working on, remember that most permaculture projects grow incrementally. The design process should focus most attention on the most immediate steps. But also keep in mind the long-term vision. Remain flexible and open to new ideas.

Analyze Resources

Site analysis

Carrying out a permaculture site analysis is the first step in creating a complete site evaluation for your land. The last chapter of this book, **Project Planning,** contains a template to assist you in planning your project. This chapter is meant to lay out the general principles so you can start thinking about your design as you read the book. The first set of questions covers general site information:

Roles

It is important to establish the roles and expectations of the project early on: Who are the consultants? Who is the owner or owner's representative? In many cases the owner is also the consultant.

History

What is the history of the land? What was it used for? What consequences could the land's former use have on its ability to grow crops?

Surrounding community

Describe the surrounding community. What impact could your project have to the surrounding community? What businesses, industries or services are available nearby that could benefit your project? For example, farming co-ops, hardware stores, tourist attractions, markets, schools, etc.

Soil type

Knowing what type of soil is at your site can help determine the placement of a garden versus placement of a building. You can take multiple soil samples from around your site or near where you want to develop. Knowing the soil type can suggest the type of crops we can grow. For instance, if the soil is salty you may want to plant pioneer plants like legumes and sunflowers to help fix nitrogen and restore soil fertility. Learn more about *soil tests* in the soil section.

Climate

What is the climate like? Tropical, sub-tropical, temperate, arid, coastline. Describe the seasons by months: Rainy/dry season, summer/winter months. What is the annual and monthly rainfall/precipitation? Temperature range? Read more in the *Design strategies* chapter.

Set Goals

Mission/vision

What is the owners motivation? Why do they want to do this? If you are working as the consultant, try to craft a statement with the owner that can help guide the site plan's overall theme. Some examples:

> "We aim to be a self-reliant demonstration site using permaculture design principles."
>
> "We aim to redesign/renovate our guesthouse to reduce energy and food costs, take greater control of the food we provide, and inspire our guests with more holistic accommodations."
>
> "We aim to use part of our property to test permaculture techniques that could be applied in surrounding communities if successful."

Project Goal Setting

Refer to the list of permaculture principles and choose goals which relate to what you're trying to achieve at your site. It is also helpful to identify more specific goals to further illustrate *HOW* you will achieve each of those goals. These are called SMART goals. SMART stands for Specific, Measurable, Articulate, Relevant and Time-bound. Each of these adjectives help determine *HOW* a goal can be achieved. For example,

> "Build a dry composting toilet suitable for 10 people using primarily natural building materials by the end of June."
>
> "Establish sleeping quarters for 10 people by the end of August."
>
> "Grow enough food for 10 people using only stored rainwater by the end of the year."

Design

Long-term project plan

A project plan in permaculture is the list of appropriate elements for a site. This book is written to present basic options available for permaculture design and help guide one through the decision-making process. Long-term planning is critical for accomplishing work more efficiently and effectively. Be creative. Think big.

Designing for space

Permaculture design is all about efficiency of space. It's about trying to obtain a higher output within a smaller amount of space. It addresses the question – how can people produce more with less space? To get you started brainstorming, here are some general estimates for minimum quantities of basic living elements per person. All of these numbers are relative. Use these only as general reference points:

How much water pp / pd?	30 L per person per day
How much food pp/pd	At least 3 sq m per person per day (ref. Square Foot Gardening)
How many people per toilet?	5 people per 1 toilet per person (min)
How many people per shower?	5 people per 1 shower per person (min)
How much sleeping space per person?	3 sq m per person

Existing conditions/permitting

Make sure all planned element and program installations are in line with all local rules and regulations. This will avoid conflict before it happens. What permits are required to do the work you want to do? Is the site zoned for this kind of building? What are the available utilities – water/power/Internet?

Maps

A map illustrates the relative location of things and places in a region or time. There are several types of maps you can create to help illustrate the existing natural conditions of your site as well as your permaculture design.

Satellite map

Zoom in to the boundaries of your site or the zoomed in area you will focus on, on Google Earth or Google Maps. Make sure you are in the satellite option (instead of the road maps option) to get a clear picture of the physical surroundings. Then, go to the **file** menu and scroll down to **print**, to print an image of your site.

Satellite image Panya Project 2008

Site map

There are several methods you can use to start drawing a site map:

1) You can use the **print** a satellite image from Google Maps (as described above) or,
2) If you don't have access to a computer, you can walk the boundaries of your site and **sketch** the perimeter. (Note: Keep in mind this initial site map is just a sketch to be used as a reference guide for a group of people. So getting exact dimensions isn't completely necessary.)
3) Now, on another sheet of paper, draw a clean outline of the boundaries of your property. **Boundary lines** mark the outer perimeter of your site.

Map basics

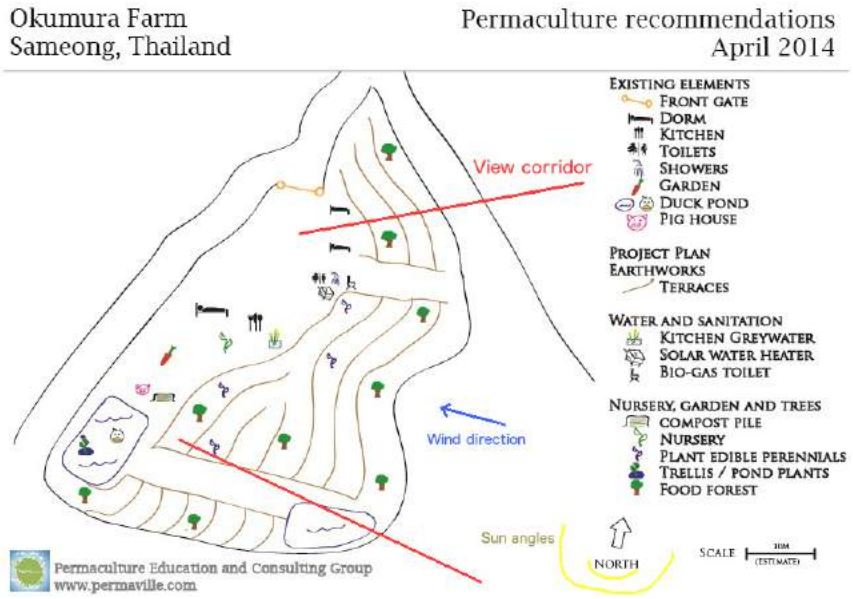
Here are a few other elements you could include on your site map:

- **Existing structures** – Indicate existing buildings, public space, forests, gardens, roads, bridges, paths, water bodies or any other important existing features.
- **Planned structures and elements** – What you want to do. Gardens, forests, structures. Think about it, discuss it, mark it on the map. It's okay if it changes – writing it down is the first step to making it real.
- **Legend** – Include symbols or labels to indicate all information on your map. Include the name of the project, location, climate and your name.
- **Scale** – Include a scale to show the relative size of the site. Scale can be measured using the printout from Google Maps.
- **Compass** – Indicate where North is

Natural sectors

Sectors are the *natural factors* that affect the land and the production levels of the land. Consider these natural factors when placing elements around your site as well as when designing structures. Natural factors to indicate on your site map include:

1. **Sun angles** – Sun angles show where the sun shines during the day and at different times of the year. Using sun angles when positioning structures and gardens can help maximize the hours of sunlight on the garden and hours of shade your home receives.
    - One trick to find sun angles from one position is to face the sun at noon, then stick out your arms in a 90-degree angle from your body (in the shape of a V). This part of your property receives the most sun.
2. **Wind direction** – Intermittent wind can damage trees and plants. Plant hedgerows or windbreaks in windy zones to break up the wind before crossing through your site.
3. **View corridor** – Determine where the best views are and design to allow the view to standout. For example, if you have a beautiful view overlooking a river, build structures to allow space so you can see the river rather than building right up against the cliff.



Okumura Farm project plan, small family with 2 acres on top of a mountain in Samoeng, northern Thailand.

Contour map

Contour maps, also known as topographical maps, mark the changes in elevation in a particular location. The distance between contour lines varies depending on the scale. It could be 1 meter or 5 meters. The difference in elevation of your site determines the scale of your contour lines. Consider the slope, terrain, types of earthworks, and elevation when designing a contour map.

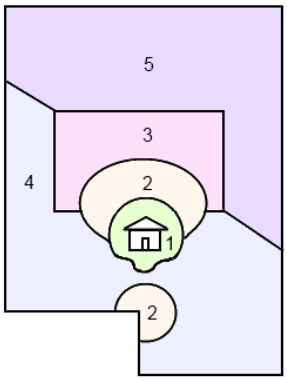
Sometimes contour maps can be found at a local government office. You can draw your own contour map as well. You can include contour lines on the basic site map, or if you will be doing many earthworks, you could make another map to show the contours.

Zone map

Zones are areas of land having a particular characteristic, purpose or designated use. In a permaculture system, everything we design should be as efficient as possible. One way to increase the efficiency of a site to consider zones and sectors of your site. There are five permaculture zones. Each zone represents a different type of land use determined by:

- How often we visit that element

- How much maintenance is required to that element
- Access to water supply: Zone 1 requires the most, while zone 5 requires the least



Zone 0 – Self or your home

You and your house are the center of your universe. They are your domain. Your center. Design from there.

Zone 1 – Visited many times a day

Zone 1 is the area closest to your house. These elements need the most attention and maintenance. Try to stack as much produce around the house so it's closer to harvest.

Zone 1 elements: Home, kitchen, shower, toilet, laundry area, clean water, annual gardens, herbs and medicinal plants, nursery, chicken coop, small fish pond, dwarf fruit trees, climbers around house, garden tool shed, compost piles (on the edge of zone 1 and 2).

Zone 2 – Visited once a day

Some elements of zone 2 can be incorporated into zone 1. For example, compost piles are also useful to keep close to your home but don't necessarily need to be in zone 1.

Zone 2 elements: Perennial gardens, animals such as poultry, pigs, ducks and rabbits, chicken coop, duck house, worm bin, small pond, compost, workshop/tool shed, milking shed, fruit tree orchards.

Zone 3 – Visited once a week

Zone 3 is generally considered as the farm zone. Here we tend to have commercial crops like corn, rice, potato etc. We also have animals for production to market or barter. It contains broad scale farming systems like orchards or food forests. Zone 3 has larger water storage systems like small dams, lakes or ponds for aquaculture and also field shelters like hedgerows and windbreaks.

Zone 3 elements: Crops for market (like corn, rice, wheat, food forest), animals for market or barter (grazing animals), polyculture (integrating different crops and animals together), domestic grain cultivation, swales and terraces, large water stores

Zone 4 – Visited once a month

Zone 4 is generally an area that borders on a forest or wilderness. It is used as larger pasture for animals like horses, cows, buffalo, sheep and goats. Or it can be used to plant tree species for a wood lot to harvest timber for building, wood for fire, thatch for roofing and fodder for animals.

Zone 4 elements: Fruit, oil and nut trees, woodlot, bamboo, grazing animals, a large water source, reforestation

Zone 5 – Visited rarely or never

Typically this zone is a natural, unmanaged environment that is not owned by the farmer or landowner such as a protected forest, nature reserve or land regeneration site. A wildlife corridor can be incorporated into the other zones to encourage native animals and birds onto your land.

Zone 5 elements: Undisturbed wilderness, preserved land

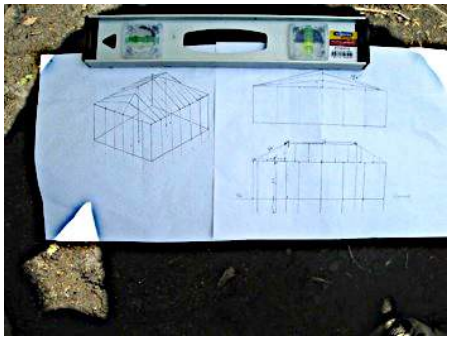
City planning zoning

Before starting a permaculture project, consult with your local council to make sure you are working within legal zoning limitations.

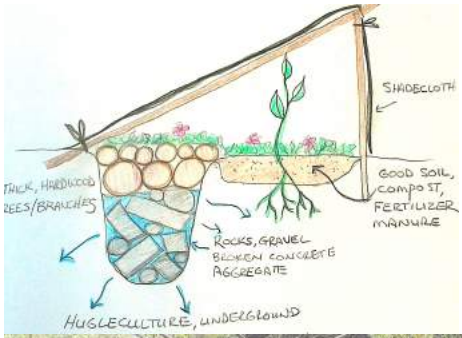
Detail drawings

A detail drawing, or detail, is a technical design of something, real or imagined. Some details can be as technical or non-technical as you prefer. Sketches, for example, are a quick, simple, casual way to illustrate an idea. Sketches are not very exact but they have just the right amount of information needed to move forward. They serve as a practical tool to get everyone on the same page. They allow for infinite design creativity at an early stage of the project. Sketches don't have to be very complex. Think simple. Here are some examples of sketches and their final installations:

Pond liner installation, Panya Project, Chiang Mai, Thailand.
This sketch (left) indicates where different lengths of bentonite liner need to be cut and set in place (picture on right has about half of the strips set in place)



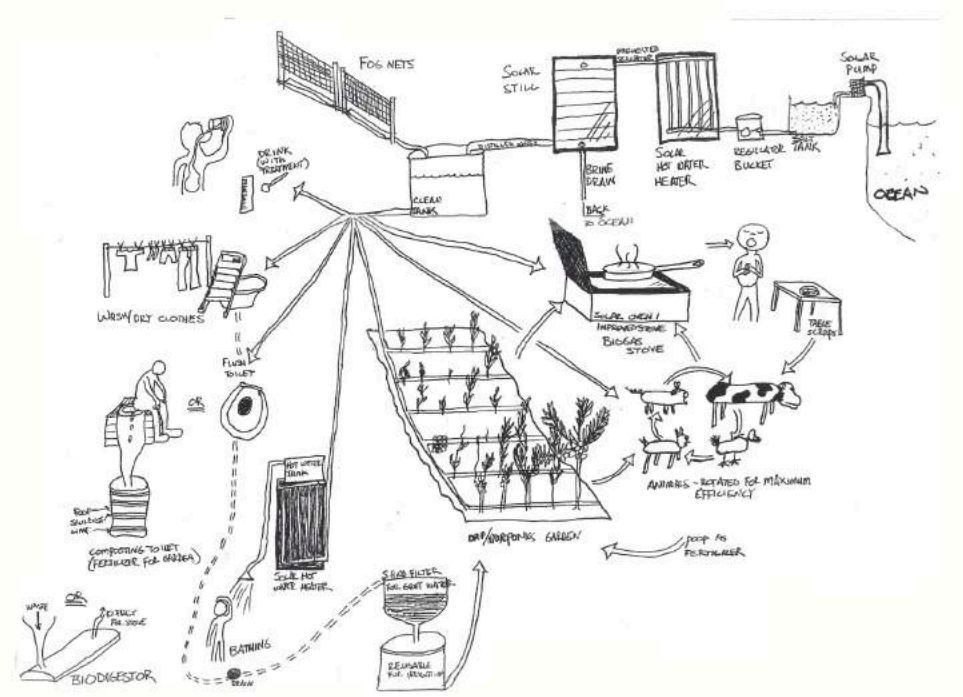
Greenhouse construction, Leogane, Haiti
The leader of this project was unable to attend the construction of this greenhouse and instead sent this design to the field team. The field team, in turn, was able to use a lot of creativity during the construction of the greenhouse.



Garden design, Kailash Akhara, Thailand
This sketch guided volunteers as they dug ~80m of trench and filled it with broken concrete and organic material. The trench collects and stores rainwater to keep the soil moist in the dry season. The shade cloth protects plants until they are established.

Flow diagram

A flow diagram is a sketch to show how different permaculture elements are related.



Flow diagram of sustainable water projects in Cape Verde Islands, Africa (US Peace Corps)

Implementation

How will you install these first projects? Will it be you by yourself or will you do it with a group of friends? Can other people participate? How? Do you need to raise funds or organize a workshop or a course to obtain the resources, labor or time required?

Project startup

What projects at your site need to be completed right away? Does your site have – access, water and structures? These are your main priorities if starting an empty piece of land. Does the site have a kitchen, toilet, shower, sleeping area, common area? Is it livable? If it's not, those should be the first things you install.

Phase I elements

Choose an amount of work you think you can accomplish in 1-6 months, with a group of people. What would Phase II look like? Phase III? Include additional phases in your design map but have a strong focus on Phase I. List the name of the element and what general details, materials and costs associated with each element.

Timeline

When will the project start, any major milestones to overcome before starting? Do you have to finish by anytime? How long do you estimate it will take to complete these tasks?

Budget

What will it cost to install phase I of your project? How about the long-term? Consider tool/material costs, food costs, transport/admin and other related startup costs. Keep in mind the long-term plan is likely to change. So keeping a budget of the immediate costs is most relevant. Here's a template for keeping track of the various expenses of a project:

Startup costs			
Project Material costs		Food and running costs	
Phase I	In USD	Phase I	In USD
Phase I material costs	**Sum 1**	**Phase I operating costs**	**Sum 2**
Total startup costs	Phase I materials		Sum 1
	Phase I operating costs		Sum 2
	Total		Sum 1 + Sum2

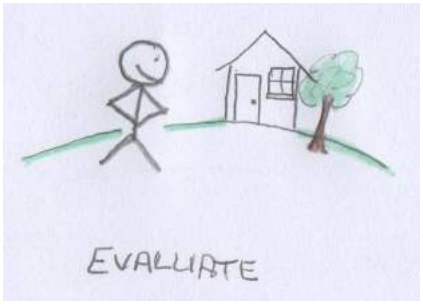
Startup budget template

Available resources

Available of resources can have much value for permaculture communities. When surveying your site, determine what resources you already have that can be used to jumpstart projects. Some examples include:

- **Organic materials** – Newspaper, cardboard, brown leaves, branches, food scraps like coconut husks, edible food, used cooking oil
- **Building materials** – Tires, glass bottles, palettes, wood, windows, doors, old couches.

Evaluate



It is important to take time to review the entire design process and determine if there are changes that could result in improvements. Once you complete an element installation, it is important to refer back to the design process and see how you could improve – did you use all available resources, did you achieve your goal, are your results measurable and quantifiable? What went well? What could be improved? Do you need to redo or rebuild something? Is it complete? You are the best judge of a project's success.

Permaculture design, like nature, is a process. Nothing is ever done. But every project, every element installation, every design must reach a point where you can say, yes, this is good enough. Let's move forward.

Design Strategies

Nature does nothing uselessly, Aristotle once said. This list of strategies helps permaculture designers make effective, natural designs for their landscape.

Holmgren's Principles

This list of principles was originally designed by David Holmgren, outlined in his book Principles and Pathways (www.permacultureprinciples.com). Holmgren's permaculture principles are thinking tools, that when used together, help us creatively re-design our environment to be more sustainable.

As you design and install elements at your site, apply David Holmgren's twelve permaculture principles to find the most effective, long-lasting solutions:

1) Observe and Interact
2) Catch and store energy
3) Obtain a yield
4) Apply self-regulation and accept feedback
5) Use and value resources and services
6) Produce no waste
7) Design from pattern to detail
8) Integrate rather than segregate
9) Use small and slow solutions
10) Use and value diversity
11) Use edges and natural patterns
12) Creatively use and respond to change

Patterns in Nature

Patterns are repeated forms. Nature repeats patterns for many reasons: efficiency, minimum effort, flow, strength, balance, stability, self-regulation or to slow down or speed up a process. By understanding nature's patterns, we can more effectively design abundant landscapes. Here are some common shapes in nature listed by examples of each:

Point

Seed

Drop of water

Wave

Tree

River

Spiral

Baby plant

Hurricane

Toroid

Mushroom

Ocean

Circle *(or oval)* *Seed* *Drop of water*

Tessellation Beehive Spider web

(Repeated shapes, of the same pattern)

Crenulation *Leaf* *Skin*

(Repeated shapes, not of the same pattern)

Edge effect

The edge effect is an ecological concept that describes how there is greater diversity of life in the region where the edges of two adjacent ecosystems overlap such as land/water or forest/grassland. At the edge of two overlapping ecosystems, you can find species from both of these ecosystems, as well as unique species that aren't found in either ecosystem but are specially adapted to the conditions of the transition zone between the two edges.

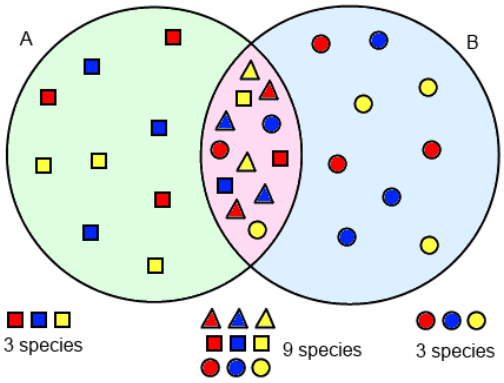


Photo and text about edge effect:
http://deepgreenpermaculture.com/permaculture/permaculture-design-principles/10-edge-effect/

In the example above, each ecosystem labeled A and B, contain only three species: red, blue and yellow. Ecosystem A contains 3 species represented by squares and ecosystem B has 3 represented by circles. In the region where they overlap, called the *ecotone*, there are red, blue and yellow squares and circles. The combination of squares and circles (which represent six species) produce unique conditions which can now support three new species, represented as red, blue and yellow triangles. So while ecosystems A and B each contain 3 species, the overlapping transition zone contains 9. The increase of diversity that results from ecosystems overlapping is known as the **edge effect**. *(www.DeepGreenPermaculture.com)*

An estuary is a good example of edge effect

Climates and microclimates

Climate is weather conditions in a general area over a long period of time. These conditions are based on conditions in the earth's atmosphere, the earth's rotation around the sun and the tilt of her axis, among other things.

Microclimates are changes in moisture level or climate on a smaller scale within a site. Worms wriggling through the soil are an example of a microclimate. Worms cause a capillary effect to happen – as they move through the soil, their bodies leave gaps in the soil which provide space for air and water to collect. This enables more microbial activity to happen and enrich the soil.

What creates climate?

- **Space** – Meteors, other planets
- **Sun** – Earth's orbit around the sun, Earth tilts on its axis and rotates around its center
- **Moon** – Ocean currents and tides
- **On earth** – Volcanoes, oceans, wind, water bodies, forest/trees, building, people
- **Elevation** - Every 200 meters = 1º temperature drop
- **Man** – Burning fossil fuels increases the expansion of the "greenhouse effect," trapping more heat in the atmosphere

Climatic zones and design strategies

Tropical / Subtropical

Seasons: 3-4 growing seasons. Hot, warm rainy season, constant temperature. In tropical regions, no months under 18ºC. In subtropical regions, can frost in the coolest months.

Rainfall: Up to 400cm a year, condensation exceeds evaporation.

Soil: Thin topsoil, soil breaks down fast. Fungi-based soil.

Note: An area supporting 180 species in a tropical forest can support 10 species in a temperate forest.

Design strategies for flood prevention, water retention:

- Flood prevention/water retention
  - Make a thorough earthworks design for flood prevention and proper water retention
- Build soil
  - Build biomass by growing legumes, perennials, and other pioneer species
  - Grow aquatic plants, they have high nitrogen content, provide shade and grow fast
  - Soil is generally acidic, consider adding lime

- Prune just before the dry season, also prune throughout the year

Temperate / High elevation

Seasons: 1-2 growing seasons. Short summer/growing season, long winter, freezing temperatures.
Soil: Thick topsoil. Soils don't break down fast. Bacteria-based topsoil.
Design strategies for cold temperatures (see *Natural Building for cold climate insulation strategies*)

Desert / Arid

Seasons: 0-1 growing season. High temperature flocculation, long hot summer, short cool winter.
Rainfall: <25cm a year. Evaporation exceeds precipitation
Soil: Little to no topsoil.
Design strategies for water retention and protecting from fire and wind

- Retain water
  - Install narrow, deep ponds, instead of shallow, wide ponds
  - Create shade, plant wind breaks, lay thick mulch (average 30 cm), ground covers, grow aquatic plants on water bodies, dig swales
  - Vines on a trellis or polytunnel create shade
- Protect from fire/wind (also on coastlines)
  - Plant windbreaks (like shrubs/hedges) and build round structures to protect from high wind
  - Plant firebreaks with plants like bananas

Earthworks

Principle: Store rainwater in the soil and provide access to the site

Rolling out a clay pond liner at Panya Project, Thailand

A permaculture community's foundational structures are its earthworks and these are one of the first areas to consider when designing your site.

Typically earthworks are thought of as swales, irrigation channels, or footpaths. However, they are much broader: think of earthworks as shaping the entire landscape of an area to maximize water retention and minimize erosion.

In permaculture, the primary goal of most earthworks is to store rainwater in the land, as close to where it falls as possible. By doing it correctly, you can diversify the landscape for food production (fish culture ponds, swales for food forests) or soil rehabilitation (swales, banana circles).

Earthworks are typically labor-intensive up front. But they return benefits over many years by creating permanent features in a landscape, which help harvest water, grow crops, and define where you live and cook.

Designing Earthworks

It is best to consider many aspects of the earth-moving process before doing any digging. Consider the following aspects of your design as you dig:

- **Design** – First, decide where you would like to place a swale, terrace, road, dam or drain, indicate the location on a contour or topographic map,
- **Soil test** – Then test the soil to see if its composition is suited to your purposes,
- **Micro-contours** – Scrape back **"leaf litter"** to expose the micro-contours of the land,
- **Contours** of the land – Using an A-frame, water level or laser and transit levels, **"peg out"** the site to indicate actual variations in elevation.

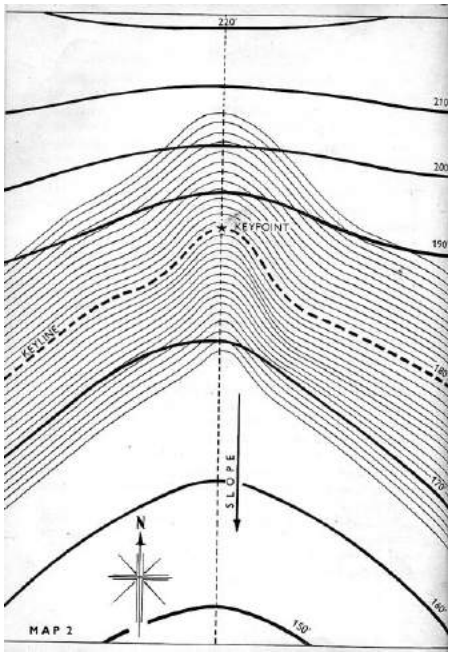
Remember - It's perfection isn't the goal, just get close, it's always an estimation. Evaluate, decide, dig in. Then keep working while you continuing to evaluate and decide.

Contour Lines

Well-constructed earthworks begin with an accurate understanding of a site's topography. Contour lines are the building blocks for your site's topographic map. They connect points of equal height of a landscape on a map. The proximity of the lines indicate the change in elevation on a landscape, which determine how and where water will flow. The closer the lines are together, the steeper the elevation.

Keyline design

Keyline is a design strategy to identify appropriate dam and swale placement along natural contours of a valley. The key point of a valley is the point where the land changes from convex to concave. Place dams along this point. A contour line from this point going in both directions within the valley is the keyline of the valley. Channel all swales away from the key point.



http://www.soilandhealth.org/01aglibrary/010125yeomans/010125ch2.html

Proper keyline implementation allows for rainwater harvesting and gravity-powered irrigation systems. Keyline design also allows soil to be compacted rather than erose in heavy rain.

Methods of leveling

A-frame – To make an A-frame level, tack three pieces of wood into an "A" shape that is approx. 2m tall and hang a weight from the top corner. Place it on relatively level ground and mark where the hanging weight falls on the crossbar. Flip the two sides around 180 degrees and mark the plumb line again. The center of these two lines marks is the middle line.

Using an A-frame

When measuring contour lines, place the two other corners on the ground you want to check if level. If the weight hangs in the middle, the two ends are level.

level

Water level – A water level is a clear hose filled with water. It works off of the principle that water always levels out to the same place in a

closed container. Place each end of the hose where you want to check if level. The water level will show if the two points are level.

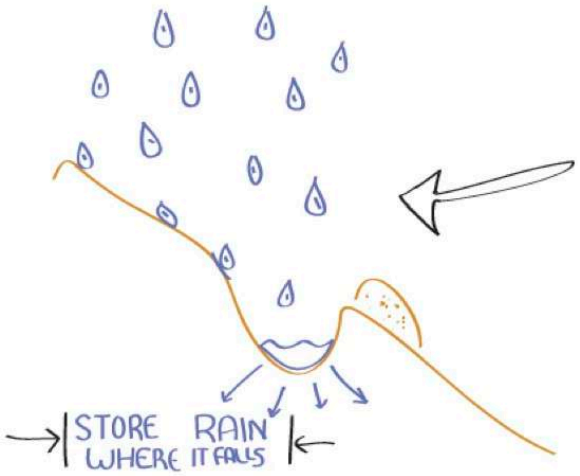
Transit level – A transit level is a tripod and a stick with a measuring tape attached to it. First level the tripod. Then move the stick to two ends where you want to check if level. If you read the same number on the measuring stick, the two points are level.

Laser level – A laser level is a more expensive transit level that dings when the measuring stick is in line with the laser.

Earthworks elements

Swales

Swales catch water from an incline and allow it to soak back into the ground. Swales can be level or 1-5% off contour to channel water down the slope to collect in a pond or another type of catchment system. Swales can significantly raise the water table in an area and are a great source of water storage for trees and vegetation. Roots will grow toward the water table and take better hold of the soil.



Swales store water in the soil

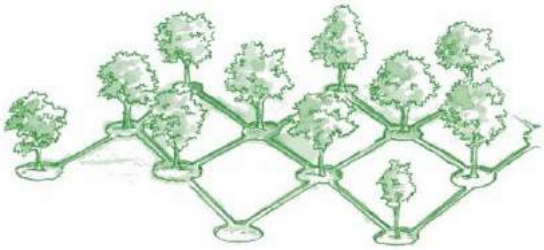
Swales play an important role in establishing vegetation. To determine how big and how close together to dig them, you consider the slope and layout of the land as well as its purpose. If you want a dense forest or a sunken garden trench, you can dig swales about a 30cm deep and 15cm and wide and allow a meter between each swale, for example. Or if you're looking for more broad scale erosion control, you can dig bigger swales (1m deep / 1-2m wide) leaving 10-

50 meters of space between each swale. It's difficult to determine the *best* spacing between swales – it depends on the slope of the land, the infiltration rate of the soil and generally what you want to do.

There is also a *swale calculator* online found here – http://extension.oregonstate.edu/watershed/sites/default/files/RainCalc/raingarden2.html . This calculator can tell you how far apart and how deep you should make your swales depending on the slope of the land and infiltration rate of the soil.

Net and Pan swales

Net and Pan swales are swales designed to catch water across an entire slope of a land. The "net" acts like a fish net, catching all of the water along the contour. The "pan" is the basin dug every few meters to catch water and store it in the ground. Planting trees in the pan provides a great source of water for trees.



From The Permaculture Designer's manual

Fish scale swale

A fish scale swale is an arc of dirt cut out around the base of a single tree. This swale will be filled with thick branches and mulch, enough to completely cover the ditch. When it rains, water collects in the swale and provides water for the tree and allows the branches to slowly decompose. This type of swale works for those who don't want a yard with "ripples" yet still want the benefit of swale systems.

There is a logical explanation on whether you should dig the swale above or below a tree. If you dig it above the tree, water will seep directly into the roots. But then if you dig the swale below the tree, water will seep into the ground and allow the roots to grow toward a source of water. Either way, when you dig a fish scale swale, you are allowing the land to absorb rainwater near the roots of a tree.

Bund

Bunds are small raised mounds. Imagine an inverted swale. Bunds are good for creating footpaths along the ridge of a garden bed. This will retain water in the garden and create a place to walk.

Terraces

Terraces are used more for planting on a slope than rainwater catchment. Terraces are flat whereas swales are more curved. Terraces create stable and productive systems. For best results, keep less than an 18% slope on each terrace. 1m is a good depth of a terrace. This allows enough space to plant some trees, some crops and leave enough space for a small path. However, the size can vary.

Terraces at Panya Project, Thailand

Drainage ditches

Drainage ditches are gently sloping water channels that flow through a property. They are used to channel water from one place to another. You want them to be steep enough to flow, but not cause too much erosion. Drainage ditches placed on the uphill side of roads are great for channeling water away from a road.

Gabions

Gabions are big piles of rocks (at least $1m^3$) wrapped in a chain link fence or other available non-organic materials. Gabions are used for erosion control on steep slopes.

Ponds

Ponds are the cheapest and easiest way to store water for later use – especially if they are located somewhere that allows you to use gravity to transport the water. There are several ways to build and/or line a pond. You can either have a pond be above ground, where you build impermeable walls, or below ground, where you dig a hole. Whichever you choose, it is important to line the pond so it will hold water.

Clay

This is the cheapest and most natural way to line a pond. You will need a very high percentage of clay (~70% or higher) in the soil for it to hold water. So first you'll need to determine how much clay is in your soil. Some methods are listed in the **"Soil"** section of this handbook. Once you've determined you have a high enough percentage of clay, pound the clay with your feet, hands or tamper to compact the clay.

Sepp Holzer, a long-time permaculturist from Austria, lined a series of ponds on his site using **pigs**. He put pigs in his pond for a few weeks and moved the pigs around to give equal time in each area of the pond. Pigs love to roll in mud. And, in this case, it worked.

Sepp Holzer's pig-tamped ponds at Krameterhof, Austria

Bentonite clay liner

Bentonite clay is impermeable when wet. It is a great material to seal a poind. You can buy bentonite clay in bags and spread it by hand, layer by layer, wetting each layer as you go. Or you can buy a manufactured liner. A **bentonite clay liner** is a synthetic liner, which evenly disperses the clay throughout a pond bottom. These liners, rugged enough to be used in industrial sites for containing toxic liquid materials, are a long-term, somewhat natural solution for lining a pond. Dependable and relatively affordable. Look online to find a nearby distributor.

Plastic liner

Plastic liners are cheap, somewhat durable and usually easy to find. You can lay soil on top of a plastic liner (up to 30cm) and lightly tamp it to protect it from UV damage. If the soil is rocky beneath the liner you can line the pond with new or used shade cloth as a protective barrier *(image below)*.

Digging a "shelf" at the top of the pond provides a space to tuck the plastic liner.

Also note the deep hole at the bottom of the pond – this provides a change of depth and if the pond happens to dry up, the fish still have a place to go.

Lining a pond with plastic liner and shade cloth in Kailash Akhara, Thailand

Ferro-cement

This is a good long-term solution for a pond liner. Ferro-cement cisterns/ tanks/ponds are durable and very flexible as far as the shape of the water system you are creating goes. However, be aware using concrete in a pond will increase the water's alkalinity.

Dams

A dam is a barrier that retains water and raises the level of the water body. The following descriptions can give you an overview of the kind of small, earthen dams that are common on many small farms.

Note: Designing and building dams safely can require a level of expertise beyond the scope of this handbook. You should consult more extensive reference works or a professional when building your own, especially because many countries require permits when constructing dams. Here are some good websites for dam guidelines: www.fao.org/docrep/012/i1531e/i1531e.pdf, http://dpipwe.tas.gov.au/Documents/Guidelines-for-earth-fill-dams.pdf

Building a dam

Dams should have a **width equal to twice the height of the dam** on all sides. This maintains the integrity of the wall. A good dam must also have a **keyway**. Usually made of rocks, gabions or reinforced cement, a keyway provides a rigid support connection between the earth and the dam.

An outlet, called a **dam spillway**, should be located about one meter below the height of the dam wall. The distance between the dam spillway and the top of the dam is called the freeboard. Never put a spillway on the front of the dam or near the keyway. Always place it on the side. Ideally the spillway should flow into a swale or some other outlet.

Once you construct the dam, it is important to seed the dam wall. Grasses like lemongrass, citronella, vetiver or napier work well to hold the bank. Don't plant trees in the dam wall as their roots can weaken it.

Types of dams

Saddle dam

Usually the highest dam in a landscape, a saddle dam is situated on the saddle of two hills. This type of dam is useful for controlling fire and/or wildlife.

Ridge-point or horseshoe dam

This type of dam is built on sub-plateaus of flattened ridges, usually on a descending ridgeline and below a saddle dam.

Key point dam

These dams are located at the highest practical construction point in the hill profile when the gradient changes from convex to concave.

Contour dam

Walls can be built on contour wherever the slope is 8% or less, or sufficiently flat. Imagine a big swale, but with walls for more water capacity.

Other types of dams

A few other types of dams to look up online: arch, embankment, gravity, buttress, turkey nest dam.

Paths

Establishing good path networks throughout your site will provide easy access to key areas and keep you from tip-toeing through

puddles after a hard rain. Consider some of the following aspects when designing and implementing site paths.

Width

1 meter is a good enough size for a footpath. Consider 1.5 – 2m if the path will be used for carts or wheelbarrows. Also, the average human step is 65cm. If you decide to use stepping stones, place stones 65cm apart, center to center, for the most comfortable step (*Barefoot Architect*).

Drainage

What is the contour of the desired path location? Where will water pool when it rains? Consider digging drainage ditches on the side of the path to whisk rainwater away.

Bund paths – As a raised, compacted earthwork, bunds are a natural location for footpaths.

Traverses – If your path is on a hill or incline, consider building a path that zigzags up the hill. This prevents erosion and makes it easier to walk.

Bevel –The middle of a path should be the highest point, sloping away from the path on both sides. This will prevent flooding.

French drain – If you know you'll have a problem area for flooding, dig a drain (30-50 cm deep), fill it with gravel and channel the water away from the path.

Medium

Having a good permanent medium will greatly extend the life of your paths. Gravel is a sturdy, cheap, and usually available medium for footpaths. The biggest drawback is that it's not fun to walk on with barefeet. Consider tiles, stone pavers or pre-poured concrete pavers. At Saelao Project in Laos, volunteers folded layers of chicken wire inside old bicycle tires, the filled the inside of the ring with cement. As it dried, they placed flat stones on the surface.

Saelao Project, Vang Vieng, Laos

Plastic barrier or cardboard – Laying a sheet of plastic or cardboard as a base layer suppresses weeds along paths. Cardboard won't last very long, but works as a short-term solution to creating a path.

Aesthetics

Try these ideas for creating an nice-looking path:

- **Grass**, pinto peanut or other groundcover plants work well in between stepping-stones. Groundcovers look nice and soak up water.
- Planting **trees** or perennials on either side of a path allow for easy harvesting and a more pleasant walk through the site.
- Footpaths should be **well-marked** at key points along the path.
- Installing solar lights or other **lighting** helps getting around at night.

Roads

If you are looking for something more substantial than a footpath, consider building a road. Depending on the use and local permitting requirements, it may be best to consult an engineer. But if you're in a bind or don't have the funds, consider layering a road as follows:

- First lay rubble, large rocks or broken concrete, on the base layer. This is the foundation of your road. (10-30cm, depending on the use).
- Lay smaller rocks or gravel to fill in the gaps of the rubble.
- Compact the two layers by driving a vehicle back and forth over the first two layers. Keep filling in the gaps as the gravel settles.
- The middle of the road should be the highest point of the road. Make sure both sides slope away from the center toward the edge. This prevents pooling or erosion in heavy rains.
- Once the first layers are tightly compacted, fill in the road with dirt or clay. Continue compacting. Maintain the slope. Monitor the road over time.

Natural building

Principle: Provide housing for people and animals

Glass bottle wall, set in cob, in-between adobe earth bricks
Panya Project, Thailand

Natural building uses primarily local and natural materials to construct durable structures. Some examples of natural building materials are earth, made into adobe bricks or cob, bamboo, straw bale, wood or stone. Oftentimes building with natural materials can cost a fraction of the price of modern homes and utilize unwanted or undervalued materials from your community.

What are the elements of a natural building? A natural building should:

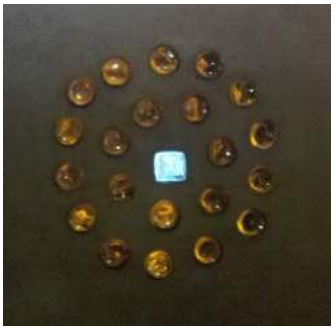
- Be weatherproof from wind, rain and natural disasters
- Be affordable by the people who live in it
- Use primarily natural or locally-sourced materials
- Have all required amenities (bedrooms, a toilet, shower, water) to comfortably accommodate its intended inhabitant
- Design using ecological design techniques

Natural building techniques

Earthen building materials

Earth has been used as a building material throughout human history. In the last 150 years, cement and other modern building materials became more desirable among the general world population. But many people now are building with earth, including people who can afford a modern concrete home. Building with earth is incredibly flexible, easy and cheap.

Earthen materials have **thermal mass**. Materials with thermal mass absorb and retain heat during the day. At night, when the temperature cools down, earthen materials slowly release the heat into the house. Strawbales (later in the chapter), on the other hand, have high insulation value, meaning they reflect a change in temperature, like a mirror. Strawbale structures have very good insulation and work well in temperate climates.

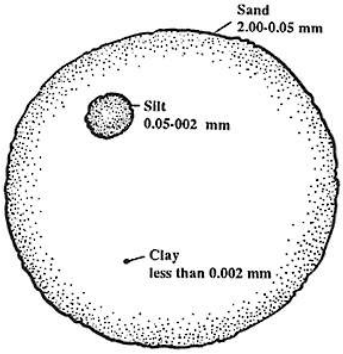


Glass bottle wall (from previous page) finished with earthen plaster

Building with earth is also recyclable. If you wanted to rebuild your earth home years after building it, you can knock the wall down and use the material from the old wall to rebuild. Just add water, turn it back into mortar and remold the bricks.

Clay, sand and fiber – The building blocks

Clay, sand and fiber are the elements of earthen building. Each of these three materials play different roles to create a very strong building material. To visualize the role of each component: think of the sand as the stone – or major building block. The clay acts as cement, binding the building material together. Fiber is the rebar, or reinforcing steel. Here is more information about each component of earthen building:



Sand – Aggregate

Particle size: 2mm - .06mm (15-500x bigger than clay particles)

Sand is a loose granular substance formed from the erosion of rocks. Sand particles are round and rigid. They make up the bulk of the substance of a wall. Sand provides strength, stability and reduces cracking in a wall.

Clay – Glue
Particle size: .002mm or less
Clay expands and contracts in size. Clay is the glue or cement of earthen mortar. It holds the mud together and sticks to the wall.

Fiber – Rebar
Fiber acts as the bones or structure of earthen materials. It is normally a dry organic material. Common types of fiber are rice husks (for bricks and mortar), straw or dried grass (for cob).

Earthen mortar

Earthen mortar, the base material of earth building, is a mixture of sand, clay and fiber. When mortar dries, it creates a very strong, rock hard, fireproof, well-insulated material.

To make earthen mortar, mix clay (15-50%) and sand (50-85%) together. Add water. Mix to even consistency. Add short fiber, like rice husks if you are using it as a rough plaster or adobe bricks, or use long fibers (like dry straw) if you're making cob. You want enough short fibers so it scratches your hands or feet but is still predominantly mud. Mix until the fiber is completely covered with mud.

The recipe for mud is flexible. Aim for a consistency of peanut butter, sticky but not too sticky. If it's too sticky, it has too much clay and will crack once it dries. Add more sand. If it's not sticky enough, it won't stick to the wall. Add more clay. Once you work with mud a few times and observe the results, you'll get a feel for what good mud feels like. Just remember, it's not an exact science and doesn't need to be.

Mixing mud, Panya Project, Thailand

Soil tests

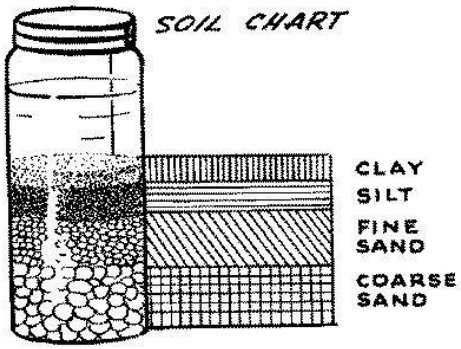
People commonly buy truckloads of sand and clay from local construction companies. In Thailand, a truckload of sand or clay costs about $15. This is an easy, cheap way to get an even mix of earthen materials. You can also use the soil at your site for earthen building. Here are a few tests you can do to determine whether your soil is good for building:

Sight test – Examine the texture of the soil to determine what it is made of. Rub it between your fingers to observe how it feels.

- If it's shiny, it has more clay
- If it's dull, it has more silt, find another material for building (see Soil chapter for more info on silt)
- If it's grainy, it has more sand

Jar test – Fill jar with soil (40%), mix with water (60%), shake vigorously, let settle for 24 hours. The separated layers give rough proportion of type of soil

- Sand particles will be the bottom layer, will settle in a few minutes
- Silt particles will be in the middle, will settle in a few hours
- Clay particles will be on top and can take up to 24 hours to separate
- Organic matter will float or fall on surface



Testing soil in jars is as simple as looking at a glass jar

No matter where you source your soil, once you start making mortar mix you need to determine whether it's well balanced. Here are a few methods to determine whether the mortar has enough sand and clay.

Hand test

- Put some mud in your hand. Slowly turn your hand over. The mix should slowly peel off as you tilt your hand. If you turn your hand over and it sticks, add more sand.
- Peanut butter is a good example of a good consistency.

Experiment with it

- Put it on a wall. If it sticks and doesn't crack, it's probably okay. If it cracks, you used too much clay, so add another layer of plaster heavy on sand. If it doesn't stick, you used too much sand. So add clay and then reapply.
- Overall good mortar mix is one with enough clay so it will stick to the wall and enough sand so it won't crack.

Mixing mortar

Mud pit

The most common way to mix mud is in a mud pit. Dig a hole, as big as you want and mix in amounts of sand, clay and fiber. It may be easier to mix the sand and clay first, then add water. Mix well with your feet and hands. Then add fiber. Add water until you get a nice consistency.

Tarp

This method works if you have a smaller amount of mud to mix or if you want to stay clean. Lay out a tarp. Put the sand, clay and fiber (once sand and clay are mixed) in the middle. Then pull the edges of the tarp back and forth. Then stop and massage the mud with your hands. Repeat until ready.

Making adobe bricks with a cement mixer, Kailash Akhara, Thailand

Cement mixer

A cement mixer is a great machine for mixing cement. It goes light years faster (hours, actually) compared to the other two methods. Once you find a good recipe (it will differ with all types of soil, make a few batches and observe results) dump the sand and clay in first. Let the machine run about 2 minutes. Add fiber. Then add water until you reach a good consistency. For general appreciation factors, it is recommended to use the cement mixer only after you have mixed mud with your feet.

Cement mixer brick-making operation, Kailash Akhara, Thailand

Adobe bricks

Adobe is the Spanish word for mud brick. Adobe bricks are sun-dried mixtures of earthen mortar, often using rice husks as the fibrous

material. Building with adobe bricks creates thick, thermal, load-bearing walls.

To make adobe bricks, first make a brick mold out of wood or other similar material. Common brick sizes are 10cm x 20cm x 40cm (standard size) or 5cm x 10cm x 20cm. These are square numbers so it makes it easy to break bricks to fill gaps as you build. When making your form, make the inside dimensions of the form measure the exact dimensions you want your brick to be.

Once you make the earthen mortar, pour it in the brick form then remove the form. If the mortar is a good mix, the bricks will stand alone. If the form sticks to the bricks, the form or the mud may be too dry. Wet and wash the form. If the brick slumps and the sides poof out the mix is too wet. Add more earthen material.

Once made, let the bricks dry in the sun for about week – turn the bricks once after 3 or 4 days. The bricks become lighter in color as they dry. If there is a chance it will rain, cover the bricks. Rain is not good for adobe bricks. When dry, store the bricks in a covered area by stacking them on top of each other.

When building with bricks, use wet rice-husk mud as the mortar to lay the bricks. Once you complete a wall, you can use the same mortar again to make a rough coat of plaster (see natural plastering below). An adobe brick wall is solid because it's the same material – in the brick, the mortar and the plaster.

Adobe brick forms for bricks 10cm x 20cm x 40cm

Cob

Cob is clay and sand mixed together, strengthened with straw. Cob uses more clay than mortar. About 70:30, clay: sand ratio. First mix the clay and sand until it is a good consistency. Then knead the straw into the mortar so the mortar covers all parts of the fiber.

Before making cob, you can soak the straw in water. This will make the straw easier to work with. You can use the cob right away or let it soak in water overnight. The longer the cob mix sits, the stickier it becomes. If it starts to smell (after a week or so), that's good. It will make a stronger bond on the wall once it dries.

When you pull the cob from the mud pit, grab a bundle of straw about the thickness of your wrist and make "dreadlocks". These long strands of cob allow you to wrap around posts, fill in a wattle (see below) or easily mold into a small brick or "loaf" to build a wall.

Cob building at Art of Living, India

Wattle and Cob

Wattle and cob is a simple way to build fences or walls using cob. You can make virtually any shape of any building using wattle and cob. A wattle is a lightweight frame to wrap cob around. Wattles are often made out of strips of wood or bamboo. When cob is wrapped around each part of the wattle, it forms a strong, non-load bearing structure with all of the beneficial properties of earthen materials.

How to build with wattle and cob

1) First make a wattle, a lightweight frame, out of bamboo or wood. The frame material should be dry. You could tie the frame together with wire or twine.

2) Wrap cob around the wattle. Cover the entire frame with dreadlocks. The more knots and overlapping of cob you can do, the stronger the wall will be.

Wattle and cobbing an arch, Panya Project, Thailand

Natural plastering, painting and sealants

Plastering, also called rendering, adds a layer of protection to a wall. Natural plaster material is the same magical material as mortar and adobe bricks – clay, sand and fiber. Many earth buildings apply two coats of plaster – a rough coat, using small fibers like rice husks to fill in the cracks in the wall, and a final plaster, using finer fibers like chopped rice straw. Two coats provide more protection for the walls. Other notes on plasters:

- The final color of the plaster will be the color of the soil used,
- Termite mounds are made of good clay material for plaster,
- To get a more sticky mix that won't crack, mix manure, flour or egg whites into the mortar mix.

Application of natural plastering

1) Scrape surface with a sharp object like the edge of a trowel to create a texture on the wall,
2) Wet the wall surface,
3) Apply 3-5 cm of mud either by hand or using a trowel,
4) After 10 minutes when it dries, go over it again with a glass bottle or a trowel,
5) For finer final plaster, sift sand and clay using an inclined sifter. Mix 3:2 (sand: clay), then add straw. For a good sticky mix, let the straw soak in water overnight. The longer the better.

An inclined clay sifter made of 2x4s and plastic mesh.
Mesh size of varies depending on the size of clay particles you want

Building with glass bottles

Using glass bottles in your adobe wall provides a creative, artistic finish. You can create beautiful artwork using full bottles, or you can cut glass bottles using a diamond cutter and fix them together for a more uniform brick shape.

Required tools: Diamond blade, 5-gallon bucket, twine, gasoline, file, vinegar, duct tape.

Steps:

1) Make a scoring block to brace the glass bottle as you score it with the diamond blade
2) Brace the bottle on the block and score at least one complete rotation using the blade
3) Soak twine in gasoline and tie twine around the bottle just above the scored line, close to the top
4) Light twine on fire. After about 10 seconds just before the fire goes out, dunk the flaming bottle in bucket of water. The bottle should break along the scored line,
5) Use a file to dress up the edges, clean bottles with vinegar
6) Do this with multiple bottles. Tape bottles together. Any tape will do, it will be hidden by the wall
7) Make a bunch and get creative!

Burning bottle wicks before dunking in a 20L bucket of water

How to make shiny plaster using glass bottles

You can also add fine glass particles for a shiny finish. To prepare a glass particle additive, put recycled glass bottles in a concrete mixer with fist-sized rocks and turn on the machine. The rocks pulverize the glass bottles and eventually return them to fine sand particles. Mix this additive in with the mortar as you plaster and it will add a beautiful shine to the wall.

Note: Make sure you use gloves when handling the glass particles – the granules are small but they can still cut you. Also note, when you put fist sized rocks into a electrical or gas powered machine, it can damage the motor. In this case, using a bicycle-powered cement mixer is a safe option.

Plastering the sala, Panya Project, Thailand

How to make natural paints

In a bowl, mix 1 cup of tapioca flour (white flour will also do) with 1 cup of water in a bowl. Boil another 4 cups of water and slowly add the boiling water to the bowl. Stir as you pour. You can add sifted sand as a rough, base coat. Then add clay to the paint for a smooth finish. To add color, you can use natural pigments like turmeric, rust, colored clay or any ground flower.

Natural sealants

Linseed oil makes a great natural sealant. It can be expensive but is an excellent natural waterproofing sealant. When applying linseed oil, first add a coat of 100% oil. With each additional application, you can dilute the oil with water. For the second coat add half water and half linseed oil. After three or four coats, the surface will appear and repel water like linoleum.

Beeswax is another natural sealant option. Or, depending on your ethical point of view, using a synthetic waterproofing paint works well and is cheap and easy to find.

Some good rendering recipes to note:
8 parts sand + 1 part cement + 3 parts fermented cow manure (to make fermented cow manure, put manure in a bucket with water for 5-7 days).

Or 1 part clay + 4 parts sand + 5 parts fresh cow manure + hydrated lime. Lime protects from rain and cow manure protects from insects.

Earthbags

Earthbag building is one of the cheapest, quickest, easiest ways to build. Also called "super adobe", rice-sack style bags are filled with dirt, laid in flat layers and strapped down with barbed wire. Like cob, building with earthbags has tremendous design flexibility and require very little knowledge to get started. Because the bags are movable and independent, earthbag structures are earthquake-proof. You can use rice sacks or look online for suppliers of long tubular sacks designed specifically for earthbag buildings.

Note: Use 20kg bags for a good width. 25kg or bigger sized bags are too wide. Turn each bag inside out to prevent the corners from filling with air. After you lay each row of earthbags, use a "tamper" tool to flatten the bag. A tamper is a heavy blunt object on the end of a stick used to flatten earth bags. It can be made from a paint can filled with cement and a hoe handle or a wooden stump with a stick nailed to the side. Once you tamp the row of bags, Then lay a line of barbed wire. Barbed wire provides just enough friction to bind each earthbag layer together.

Earthbag building, Kathmandu, Nepal

Rammed earth

Building with rammed earth is another very structurally sound natural building technique. Rammed earth walls are waterproof and require no plastering. With rammed earth, you make forms of where you want your wall to go, and add dirt. You can add 5-10% cement to the mix to provide a stronger hold. One good mix ratio is 4 parts cement, 5 parts gravel, 6 parts sand and 13 parts sifted clay. However, earthen recipes can vary depending on the type of soil you have.

20cm is a good width for rammed earth walls. As you fill the form, add 30cm of dirt, then compress to about 20cm using a tamper. Repeat this until you reach the top of the wall. When you remove the form, the rammed earth looks like layered sandstone.

Bamboo

Bamboo is a beautiful, strong grass, which can be used as a building material. There are many types of bamboo ranging in thickness and strength.

The best time to cut bamboo is at the end of the dry season. In Thailand, this is around April. If you are running short on time or it's not the end of the dry season, you can cut the bamboo and let it cure for about a week. Then set the bamboo in place. When it dries, it will hold that position. Structurally this will work. However, the bamboo is still susceptible to termites. You can also soak the bamboo in a solution of borax salt or soak them in water to get rid of the sugars for better termite prevention.

At the Art of Living Permaculture site in India, volunteers cut the bamboo and let it sit in the sun for a few days, and then built a structure before the bamboo dried. The poles were flexible because they hadn't completely dried out. The flexibility enabled the team to bend some of the poles into place when constructing the roof.

Drying freshly cut bamboo for 1 week
Art of Living, India

Chip and slip (also called straw-clay)

Straw clay is a very efficient building technique with high insulation rating. The straw provides insulation and the clay absorbs moisture. When packed into 20cm walls, this material can have an insulating value 2-3 times to that of fiberglass. It is necessary to use a form for the wall to pack the material into. Chip and slip is similar to cob and rammed earth.

Cordwood

Cordwood uses wooden stumps (10cm or wider) stacked horizontally and packed with cob and mortar. Imagine looking at a stack of wood logs where instead of gaps, there is cob. That's cordwood.

Straw bale

Straw bale provides high insulation values for a building, about 2-3 times commercial fiberglass. This is a great method for temperate climates and is very easy to build.

Living homes

Living homes are another method to construct a house that grows over time. Often called, espalier or pleaching technique, is when you plant trees in the shape of the building you would like to grow. This technique can also be used to grow food hedges and food fences. As the plants mature, you train them to grow in different directions. Espalier is the horticultural and ancient agricultural practice of controlling woody plant growth by pruning branches to a frame so that they grow into a particular shape (http://en.wikipedia.org/wiki/Espalier).

Willow pleaching

Other alternative natural building materials

You can also build using cardboard, wood palettes, plastic bottles, reeds or used shipping containers.

Unsustainable building materials

Any material that requires a lot of energy or causes a lot of pollution could be considered an unsustainable building material. Cement, steel and synthetic paints are useful unsustainable building materials. While they are made of natural materials, the amount of energy and pollution caused by these materials is unsustainable. Using these building materials can extend the life of a building by years, if done correctly.

When determining whether to use unsustainable building materials or not, consider the reason, cost and time needed to finish a project. Evaluate how long the materials will extend the life of the building. For example at the Panya Project in Thailand, the community originally built toilets with a wooden floor. Over two years, the floor rotted from the moisture in the poo chambers. New toilets had to be constructed and the decision was made to use steel and concrete for the flooring.

Every person has different reasons and ethics when approaching unsustainable building materials. Do what you want to do.

Strawbale home by Edge Architects, Taos, New Mexico, USA

Ecological house design

An ecological house is a house, which utilizes as little energy as possible to maintain the house. Ecological homes are also built using local, natural materials. Consider the following aspects when designing structures:

- **Aspect/orientation** – Consider how your house will face the sun. It's beneficial to position main elements of your site to face the sun. For example, in the northern hemisphere, point the opening of buildings or large windows to the south. In the southern hemisphere, face the opening of buildings or large windows to the north. This enables sunlight to enter the house throughout the day. A veranda or shade structure can also be built at the west side of the house to cool the house at night. Buildings with proper orientation can reduce 7-10% of energy consumption.
- **Ventilation** – Consider wind flow through the house.
- **Natural lighting** – Adding lots of windows, open spaces or sky lights are good ways to allow more light into your home.
- **View corridor** – Think about the spectrum of view you will have once the house is built. Look around the site of the building. What is nice to look at? Build the house to face that.
- **Round walls/shapes** – Consider building a round house for more unique and natural design. Note: As you're constructing a round house, the walls don't have much strength. The moment you complete the circle, the walls will turn to stone. Be patient, stay with it.
- **Big hat, big boots** – To prevent damage to earthen materials from rain include a .5-1m roof overhang and good foundation.

Insulated Greenhouses

- Build using cob or strawbales to regulate temperature.
- Build a pond to collect and store heat (water has high thermal mass and naturally store and release heat).
- Put a compost pile inside or keep rabbits, chickens, guinea pigs under tables inside. Heat from the compost pile and animals is contained in the room.
- Build heating ducts of cob throughout your house, attached it to a wood oven.

- Plant deciduous in front of big windows. They gain leaves in the summer which create shade and lose leaves in the winter to let sun into the house.
- Build a cellar or a pit to store food for winter food storage. The temperature is steady underground.
- Plant trees in an arc to create a suntrap. Once the trees mature, the arc retains heat from the day.
- Install ponds (in all climates) to regulate temperature of the soil and the air.

Tropical building strategies

- Build on stilts to prevent flooding around structures,
- Collect all rainwater for the dry season
- Build an outdoor kitchen and/or bathroom
- Steep roof for shedding rainwater (if using thatch)

Arid climate building strategies

- Central courtyards
  Small windows
- Build underground
- Green roof
- Evaporative cooling

Building strategies for earthquakes

When designing buildings in earthquake-prone areas, consider constructing buildings with high sheer strength.

Pyramid-shaped home

A tetrahedron-shaped home divides the load among four points. When each point is anchored, the structure is as strong as a pyramid. If an earthquake ripples the ground, the points can each move independently without damaging the walls. Designed by Canadian architect Bernard Fredette at SuncampDR in Dominican Republic, www.suncampdr.org.

Dome home

A dome is the strongest structural shape for a building. The weight is evenly distributed throughout the structure. If an earthquake occurs, the building will distribute the weight and the structure will hold together. Steve Areen of

www.steveareen.com/domehome/ built a dome home out of concrete blocks in Thailand. The project took him six weeks and cost 9000 USD.

Steve Areen's house in Thailand
www.steveareen.com/domehome

Earthships

Earthships is a building technique/organization that uses only waste materials, i.e. tires, glass bottles reclaimed windows and doors. Pioneered by Michael Renyolds, a natural builder from Arizona, USA, Earthships are now building homes worldwide in disaster prone areas and offer building internships to learn the Earthships design. Watch *Garbage Warrior* for the story of Earthships or look them up online to learn more.

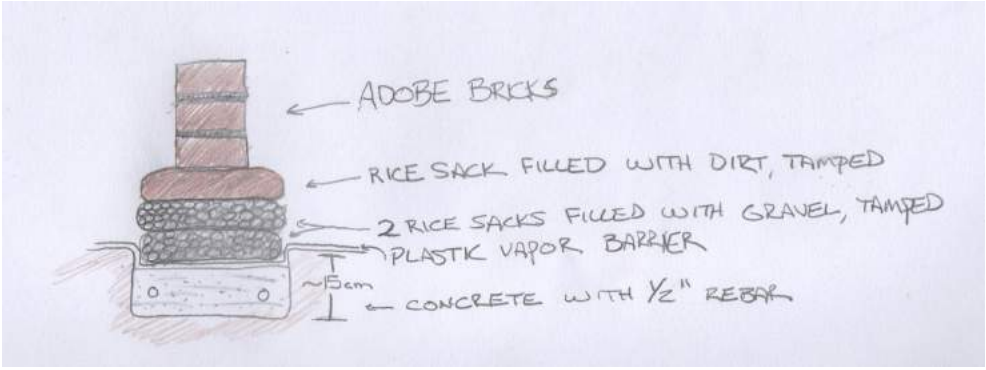
Pleaching/espalier

As mentioned earlier in this chapter, pleaching/espalier is a technique to plant trees in the space you want to grow them. Look at the section above for more information.

Parts of a house

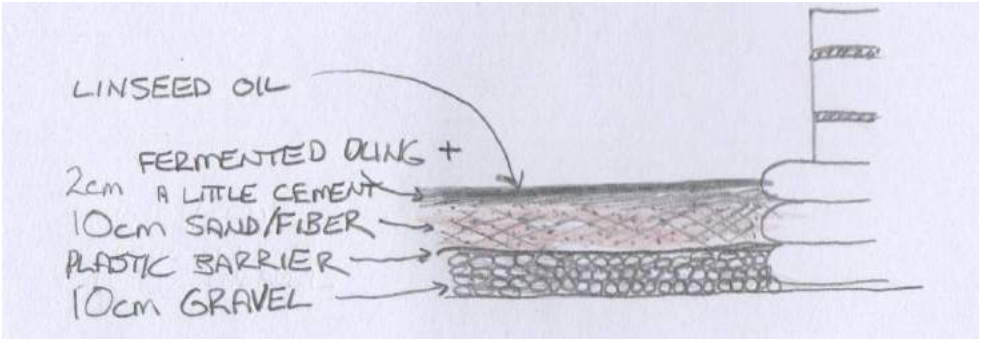
Foundation

The size and materials used in foundations vary. Here is one way to method to build a foundation (in the tropics):



Floors

A natural floor is a good way to use mainly earthen materials. Here is one method for installing a natural floor:



Sketch of a natural floor

Roofing

If you want to build a free-standing roof structure, consider a reciprocating roof style. This works best if the diameter of the house is less than 6m.

Continuous spiral roof, Milkwood Permaculture, Australia

Roof material

Tin roof – Tin is a very common, available and relatively cheap roofing material found in most countries around the world. This material makes it easy to collect rainwater and will last years if installed correctly.

Tarp, fiber, shade-cloth combination – The Bamboo Center in Auroville, India innovated a lightweight, prefabricated roof structure that lasts years. To construct, build the roof frame on the ground, then wrap the frame with the three materials, first tarp, then shade-cloth and the natural fiber. The combination of the three gives a natural look to the roof and work together to combat damage from the sun.

Tarp, fiber, shade-cloth roof style, Auroville, India

Clay tiles – Clay-baked tiles are a great, long-lasting way to protect a building from rain. These tiles can be expensive and are heavy, so they will require a good roof structure.

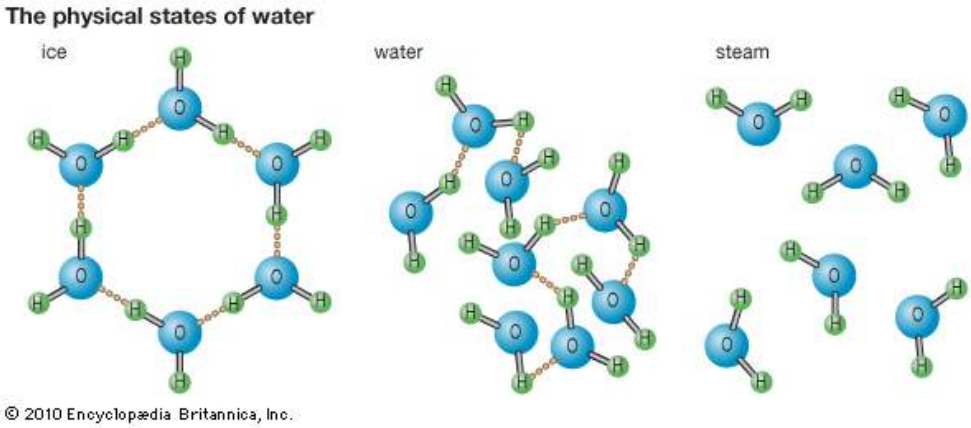
Thatch roof - Thatch is dried straw. It creates a beautiful, natural roofing material. Check online for tips on weaving thatch. In many areas you can buy pre-made thatch for very cheap. When assembling a thatch roof, you want the roof to be as steep as possible, over 45º. The steeper the incline, the more water is shed from the roof, thus preserving the life of the material. If the roof is less than 45º, the roof won't last more than one or two rainy seasons.

Water

Principle: Clean, conserve and reuse water

Water is a unique, abundant, life-supporting substance. Understanding water's properties and effectively managing its use are critical to the success of your permaculture site. Some unique properties of water include:

- Thermal mass. Water resists temperature change and acts as a battery for heat.
- Expands and contracts, when it freezes and melts.
- Capillary action. An example of capillary action is when you dip a piece of string in a cup of water. The water wicks upwards. Water defies gravity, in some words.



Some estimates show Americans consume an average of 350 liters of water per person per day, Europeans consume 120 liters and Africans

consume 3 liters. While this statistic varies among people, communities and countries, it is important to note we need to find a balance. How much do we really need? The United Nations decided 30L is a good amount of water per person per day. A daily average is a good method to determining the size of your site's water storage capacity (number of people x daily consumption x number of days of the dry season = needed volume of storage).

Of all of the water in the world

97% is salt water and 3% is fresh water. Of the 3% fresh water:

- 75% is frozen in snow and ice
- 24% is in aquifers (deep and shallow),
- .5% is in rivers and lakes, .3% is in forests and soil and .2% is the in atmosphere

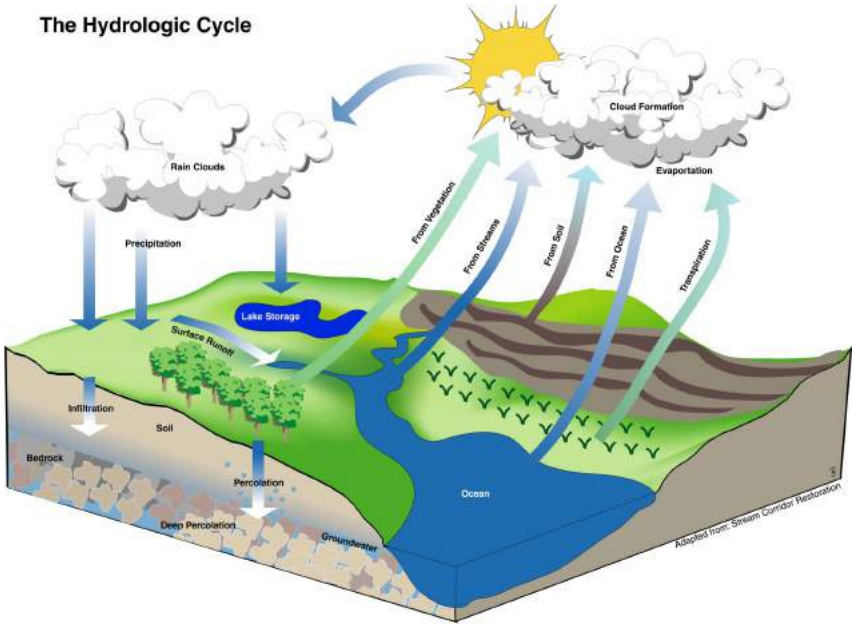
Good permaculture design water strategies

Here are a few strategies to conserve and store water in tanks and in the soil. Keep these in mind when designing your water site plan:

- Create the longest path, moving as slowly as possible (the most *passive friction*), passing through as many living things as possible is the most fertile design.
- Overall, a good water design has 10-15% of a site include water (PA Yeomans)
- Dig effective ***Earthworks*** to slow, stop and soak water into the soil,
- Plant layers in your forest. Rain soaks into the vegetation before it hits the ground. This allows trees and plants to absorb water. (more in *Trees*)

Hydrological cycle

Water follows a similar pattern as it rises and falls from the sky. The hydrological cycle goes as follows:



Hydrological cycle

Human water cycle

Water also follows a similar pattern in relation to humans. The human water cycle goes from the source to filtration to transport to consumption to recycling.

Source

We can procure water by catching and storing water from the air, from the ground or from below the ground:

1) Collecting water from the rain and fog – rainwater capture and storage strategies are present in nearly every permaculture site.

Rainwater catchment

Rainwater catchment is a gutter system installed on the bottom edge of a roof to collect rainwater. When the water is collected in a gutter, it channels the water to a downspout and collect in a bucket or cistern.

1st flush system

A first flush system is a drain built into a rainwater catchment system to wash away the fallen debris on the roof at the start of a rain. There are several designs for a first flush system.

Fog Nets, Cape Verde

Fog net systems catch water from the air. They are most appropriate on mountain ridges where clouds frequently pass over. Large plastic mesh nets are flown 3-10m in the air to capture water from the passing clouds. At the base of the nets, a 10cm PVC pipe catches the water and channels it to a collection tank.

Fog nets, Cape Verde Islands

2) Collecting water in ponds and tanks on the surface of the earth – Storing water on the surface of the earth provides habitats, fish, food, irrigation, recreation, etc.

Ponds

Building ponds increases the aesthetics of a site, as well as plant and fish diversity. Small ponds are great for edge effect, enabling greater species diversity to take place. (See the *earthworks* section for methods on lining ponds.)

Water equilibrium principle: If you want to store water in multiple places in your site, you can connect cisterns using PVC pipes. Water tanks level out when connected by pipes. Consider this when designing and installing your site's water system.

Water tower

An above ground water tower uses gravity to create water pressure throughout a site. Note: Each 30cm (1') of water raised creates .43 psi (pounds per square inch) of water pressure. Water pressure in conventional public water supply systems are about 40psi. If

designing your own water tower system, 8 psi is a good minimum, or between 6-8m as a minimum height for decent pressure.

Water tanks

Ferro-cement tanks

Ferro-cement is a great method of building water tanks or cisterns. With this construction technique, you can design any shape you like. Lightweight <500 gallons (2000 liters) = use 1/4" rebar. Medium 500-2000 gallons = use ½" rebar (metal rods commonly found in hardware stores).

Cistern, above or below ground

A cistern is a vessel for storing water. Cisterns are often connected to rainwater catchment systems to store water and provide water security. Cisterns can be built above or below ground:

- Above ground cisterns can be built with mud bricks or earthbags and lined with cement mortar.
- An underground cistern is a large hole lined with cement or plastic and covered with a cement top.

3) Below the surface of the earth

Wells

Wells are underground holes dug to pull water from the water table. The cost of drilling can be expensive, but wells provide a steady source of water for a community. Pulling water from underground in wells is a last resort for sourcing water.

Transport

Once water is ready for consumption, it is transported to our communities and homes either through metal or PVC piping systems, trucks or fetched on foot. Here are a few methods to get water to where you need it:

Water Pump

A water pump is any mechanical device that forces water to flow in some direction. There are many types of water pumps and designs. A few common water pump designs are hand pumps, ram pumps, jet

pumps, submersible pumps and siphons. The most economical and simple water pump is powered by gravity.

Bicycle water pump

Water Canal

Canals can be built above or below ground. For a hidden water canal (often called a French drain), dig a trench in the low area of your site about 30-60cm deep and wide. Then line the trench with small and medium-sized gravel. Cover with dirt. For a visible water canal, you can dig the same sized trench and line it with concrete or clay (if you have a high percentage of clay in the soil). This can be used to channel water.

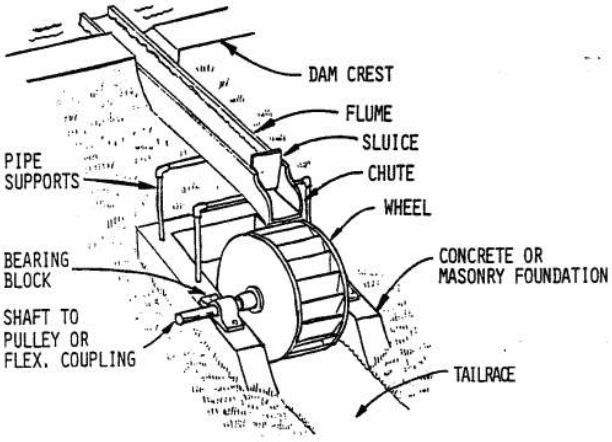
Windmill

A windmill is a structure with vanes that rotate in the wind to pump water or grind grain into flour. Wind turbine usually refers to machines that generate electricity and windmill refers to powering more mechanical devices.

Water Wheel

Water wheels are devices placed in rivers to slowly and consistently pull water from the rivers. As the current flows, the wheel scoops up water and raises it to a higher elevation. Here is a good video of a water wheel: http://www.youtube.com/watch?v=LbklIccv2CI. This constant source of water can be used to fill a cistern.

Water wheel uses pvc bent to form a circle



Detail drawing of a water wheel

Plumbing

Plumbing is a system of PVC pipes and drains to distribute water where it is needed. This is how most developed communities transport water. One good rule of plumbing to remember – water (and poo!) roll downhill. Use gravity to your advantage.

Water Filtration

Here are a few low-energy, low-cost methods for producing clean water:

Solar Still

Solar distillation is the process of capturing evaporated, or distilled, water using solar energy. A solar collection box

heats water which evaporates, leaving salt, many pollutants and bacteria behind. As the water vapor cools it condenses into a collection vessel. There are several designs of solar stills. This method works however has proven not to have the highest output (*Image: Solar still, Cape Verde Islands*).

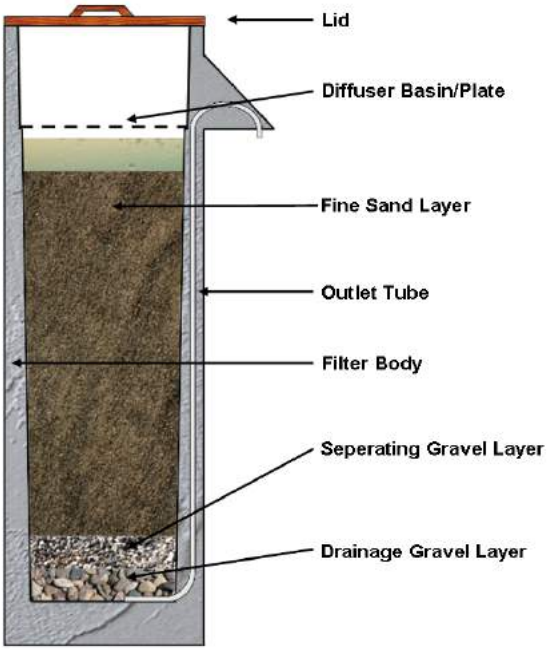
Ceramic Water Filter

Filterpure ceramic filters are 20L charcoal/silver-lined clay pots which can filter up to 20 liters/water a day. The ceramic filter can remove all bacteria and some viruses including e coli, salmonella and cholera. Go to www.filterpurefilters.org for more information on the Filterpure filter. To increase the clean water output, a 5-gallon bucket can be glued to the top of the filter with silicone putty. When the bucket is filled, the added water pressure increases the output to 60 liters/day.

An Aquapure water filter can filter 20 liters a day
Dominican Republic, www.filterpurefilters.org

Bio-Sand Filter

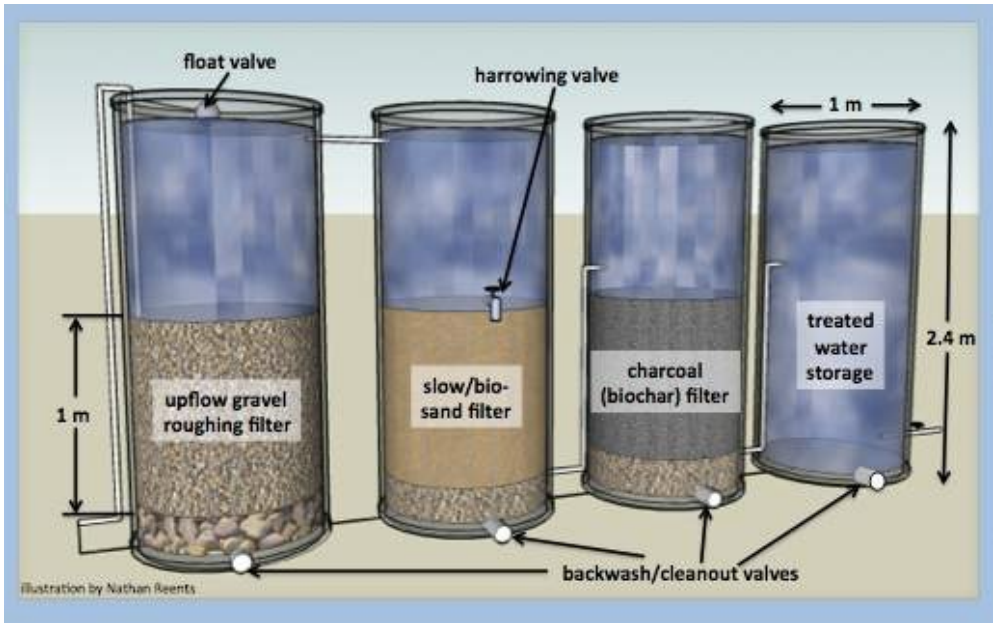
Bio Sand Filters are a multi-barrier system to filter water, and can serve as a long-term filter for a family requiring little maintenance after the initial build. Water is poured into the top and trickles through several layers of sand and bacteria to produce several liters of clean water a day. They remove bacteria, heavy metals, viruses and can dramatically improve the taste of water. This is a good system for residential use and can work for a long time as long as the filter remains wet.



Bio-sand filter

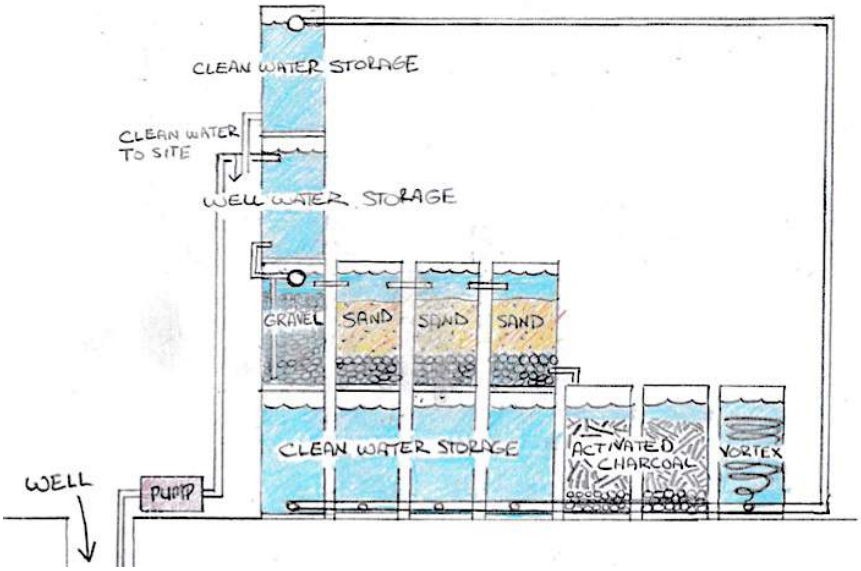
Multi-barrier water filtration system

This filter, designed by Aqueous Solutions (www.aqsolutions.org) filters 2000L of water/day (about 1 L/minute) when running properly. It is very cheap to make, easy to construct and effective water solution for a community of up to 100 people. This system is expected to last 5 years before needing to change the filtration material.



Multi-barrier water filtration system,
Illustration by Nathan Reents, Pun Pun/Aqueous Solutions

Note: When installing the filter, you may want to add an additional 1 or 2 sand filters. This is the slowest part of the system. If you add additional sand basins, the system should reach the potential output of 1L per minute.



Water filter/tower/storage design

Water heating

Here are a few unique ways to heat water for showers:

Solar water heater coil

A solar water heater can heat water for the shower, washing clothes or cooking. One simple way to build a solar water heater is to wrap black hose into a large coil and place it on a roof that receives a lot of sun. As you use the hot water, cold water will replace the hot water in the tube and begin heating. Google *Greenpowerscience – solar hot water* for more information on solar water heater coils.

Solar water heater box

For a good, immobile solar water collector, build a box out of cement and mud mortar, add insulation to retain the heat. Build the structure facing the sun. Then install one or two 200-liter metal drums, depending on how much water you want to heat. A two-barrel box structure would measure about 2m x 2m x .8m on the interior. Connect the bottom of the drums to a cold input line. Run another line for the hot water to exit the drum on the top. Then cover the box with a sheet of glass or clear plastic.

Solar water heater box, Panya Project, Thailand

Long-term compost water heater

For a cheap, reliable source of hot water, build a long-term compost pile and wrap a 50m garden hose through the pile as you stack the pile. For the long term compost pile, first lay large sticks or branches on the ground, then stack brown and green material (as you would a normal compost pile), add lots of manure or other high nitrogen additives. Add water with each layer. This pile won't be flipped, it will slowly decompose. Connect one end to a water source and run the other end into your shower or wherever you need it to go.

Outdoor Showers

Outdoor showers provide a great place to bathe in the sun. The structure just needs access to water, adding a **hot water heater** is a bonus. Grey water can be passed through a sand filter and used to water plants. Make sure to tell people to use natural soap. If you use strictly natural soap, you could pour the greywater directly onto a garden bed. Otherwise, it may be best to run the water through a greywater system (also in water). Here's an interesting portable shower design: https://www.youtube.com/watch?v=FC4nihIuKAM&feature=fvwrel.

Laundry area

A covered outdoor laundry area is an area to wash clothes. This must have access to water, proper drainage and several large bins for washing clothes. Grey water from this system, like the showers, can be used for irrigation. You may also want to include a clothesline or clotheshorse, an area for drying clothes.

Hand-Washing Station

A drip hand-washing station provides people a place to wash their hands. This element can be installed near a toilet facility for people to use after using the toilet.

Drip hand-washing system, Sadhana Forest, India

Water recycling

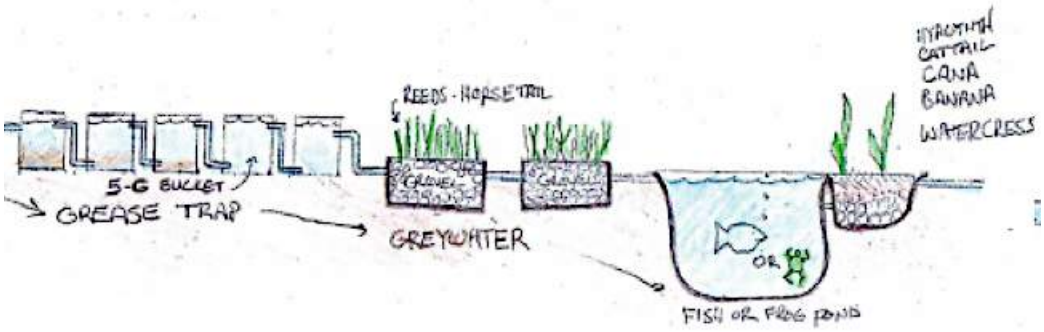
After you consume water for basic needs, it is important to recycle the water.

Greywater is the effluent from a kitchen, shower or laundry area. The drain of a shower or a kitchen sink can be connected to a grey water system to recycle the water or filter it for use in the gardens. Blackwater is effluent water from flush toilets *(more in sanitation)*. Here are a few ways you can recycle your greywater: Check out *Creating a Greywater Oasis* for more information.

First for the kitchen greywater, you can install a grease trap: A grease trap is an essential element for any kitchen. Here is a picture of a homemade grease trap using a 20L bucket drain system to filter out the grease. It's basically a 5-bucket settling tank. By the time the water reaches the last bucket(s), the sediment will be filtered. Put a smaller bucket inside the bigger bucket and punch holes on the side, to remove the grease. Empty the grease traps about once a week. The grease or "sludge," can be dumped in a biogas container.

Bucket grease trap (source online)

From the grease trap, run the water into a concrete ring or other type of impermeable container. Fill the container with gravel. Sediment in the water will stick to the rocks and break down. Plant reeds, cattails or woody water plants to filter the water. You can direct the overflow water into a pond, where fish and pond plants will continue to munch on nutrients in the greywater (more in aquaculture).



Greywater design

Sanitation

Principle: Produce no waste

Recycling bins, Panya Project, Thailand

Waste, by definition, is material that is not wanted. Sanitation refers to conditions related to waste, especially as it relates to sewage and commercial waste disposal. As a human culture, we typically regard feces as waste and we throw too many things away. As a result, we squander a tremendous amount of water, our landfills are bursting and there is a toilet bowl of garbage in the ocean. As a culture, we have a problem with sanitation.

There are generally two types of waste important to a permaculture site – poop and trash. In this chapter, we will address both and see how we can make use of them before they become "waste".

Commercial byproducts

Commercial waste includes things we buy, which eventually become something we can't use. Common waste materials around communities include aluminum cans, glass bottles, plastic bottles, palettes, cardboard, newspaper/paper, food scraps, plastic bottles, metal scraps, plastic wrappers, glossy magazines, plastic bags and packaging.

Ways to cut down on waste

Refusal - The first step is to avoid it altogether – don't buy or acquire things. Yield not to buy or cut back buying things when possible. If you have to justify to yourself why you need to buy something, you probably don't need it.

Recycling Bins – Recycling bins provide a place to recycle glass, plastic, plastic bottles, metal, paper and other waste. These recyclables can be reused for gardening or craft projects. You can use glass or plastic bottles for building, sell the metal or aluminum cans and use paper to start fires. Then you're left with plastic and other waste (see site landfill below).

Common household waste materials

Building materials – Aluminum cans, glass bottles, plastic bottles, palettes

Gardening materials – Cardboard (good for sheet mulching), newspaper/paper, food scraps (both good for compost), plastic bottles (drip bottle technique),

Free Box

Maybe the stuff isn't waste after all! A free box is a place for people to dump off things that are no longer useful to them but may be useful to someone else. Instead of reselling them at a low price, all of the things in a free box are free. This element works for small hostels or volunteer camps because there is usually a high turnover of travellers. And travellers are always looking to dump some things off or pick up some cheap, new clothes.

Disposal

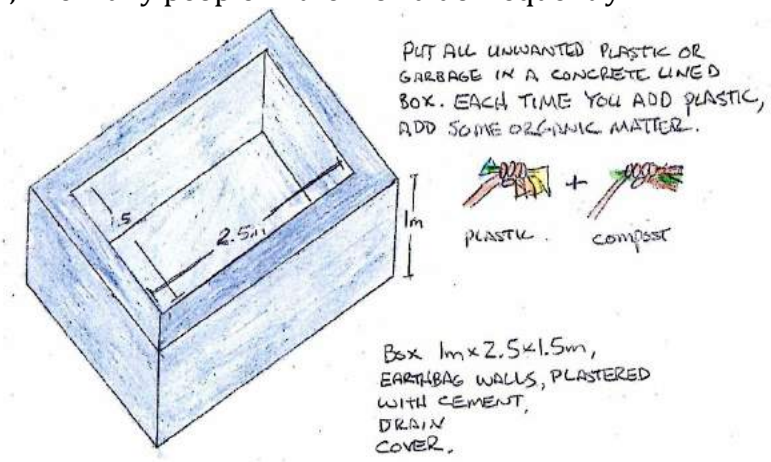
Waste disposal is a challenge. Either you get rid of it yourself or you give it to someone who will do it for you. And that usually consists of them dumping it a landfill or burning it. For general sanitation purposes, it's good to consider how to contain all waste within your site. Here are a few ecological ideas for garbage disposal:

Site landfill

To contain the harmful byproducts from your slowly-degrading inorganic waste, you need to build something to hold it, like a concrete ring (1m).

Throw all of your waste, which should be mainly plastic after recycling what you can, into this container. Containing all of the waste here will prevent toxins from seeping into the soil. You can either cover the ring or leave the box open to allow the UV rays to break down the plastic.

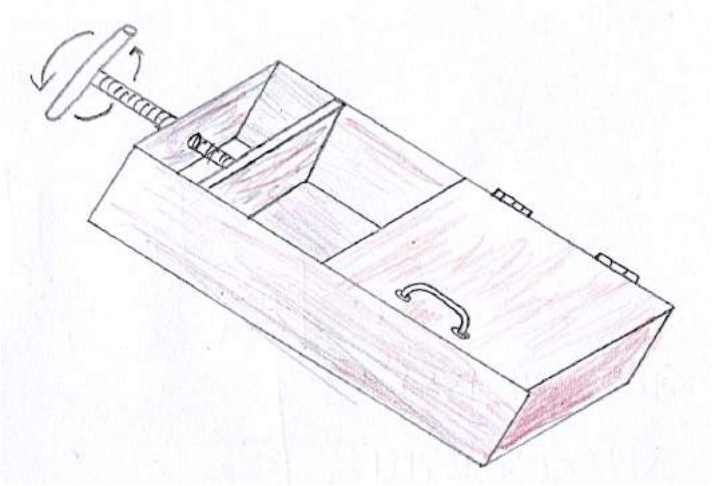
There is not much known for certain about the best way to break down inorganic waste, so this idea would be more of a concept for research. The idea would be to see how much plastic you could decompose using simple techniques like sunlight and fungi. Considering the alternatives like putting our trash on the street and having someone else put it in a landfill (most likely) or burning it yourself, like many people in the world do frequently.



Conceptual design of a site landfill

Trash compactor

One way to get rid of trash is to compact it. You can make a trash compactor by just making a wooden box and then use a compacting arm to mash the trash into the size of a brick. Use wire to hold the brick together. You can reduce the trash volume by 50-90% depending on the type of trash your compacting. Here's a good article about compressed garbage: *http://www.motherearthnews.com/green-homes/recycled-plastic-block-houses.aspx#axzz3791jtKqi.*



Trash compactor

Incinerator

Many people worldwide burn their trash. This emits toxins into the air. One way to avoid inhaling the toxins, if you do choose to burn trash, is to make a burn ring away from where people hang out at your site. Put all unwanted, flammable, trash into a 200L metal drum and burn it. It pollutes the air terribly but allows you to get rid of it. There is research to be done on small-scale garbage incinerators.

Waste-to-Energy

Waste-to-Energy ("WTE") is a system designed to completely eliminate trash through incineration, energy recovery and recycling of the fly ash. The incinerator burns the trash and uses the heat from the fire to boil water, turn a steam engine and make electricity. Then the smoke and fly ash from the fire is collected and compacted into dense blocks, which can be used for construction. Look up Sysav (http://www.sysav.se/) to read about a Swedish WTE company which is consuming most of the garbage in Sweden.

Methane Collection Facility (Landfill)

Landfills are an enormous source of methane, a gas that seeps out of decomposing garbage. This gas is a potent pollutant but also a valuable energy source. Methane electrical generators are deep holes bored into landfills, which can use the gas to turn turbines and make electricity. This works more on large-scale landfills. More research needs to be done on a small scale to make this a viable solution.

Human waste

Ecological sanitation (EcoSan) is an integrated sanitation strategy developed through traditional knowledge and biological science in which natural processes are utilized to transform human wastes into fertile soil. EcoSan provides an innovative, low-cost solution to human waste problems and improves a community's general sanitation.

What are human feces made of?

These are some rough percentages of the composition of our poo and pee. While the actual percentages will vary greatly, these are listed mainly to illustrate the beneficial elements of our waste *(Percentages from Natural Farming, by Dr Arnat Tancho):*

- Organic matter (88-97%)
- Nitrogen (5-7%)
- Phosphorus (3-5%)
- Carbon (4.4-5.5%)
- Calcium (4.5%)

What is human urine made of?

- Organic matter (65-85%)
- Nitrogen (15-19%)
- Phosphorus (2.5-5%)
- Carbon (11.17%)
- Calcium (4.5-6%)

Human Waste and Hygiene Elements

Composting Toilets

Composting toilets are a way to dispose of human waste without water. There are many variations of composting toilets. A few are described below. The main components of composting toilets are that they don't use water and they have a separate facility to decompose human waste.

Types of Composting Toilets

Humanure Toilet

A Humanure toilet is a dry composting toilet for human poo. After you make a "deposit" in a Humanure toilet, you throw in a handful of sawdust, lime or some kind of drying agent. These

additions allow for the poop to immediately begin decomposing.

Contrary to what one might think, composting toilets do not smell. Once you add carbon, like sawdust, the moisture is absorbed which eliminates odor. If you add too much urine and not enough carbon, the chamber can smell. So it's good to also install a Urine Diversion (below) to divert some of the urine away from the poo chamber.

After a poo chamber has filled up, one safe estimation is to wait six months. In that time, the pathogenic bacteria will die off and the Humanure can be used in your garden or forest.

Composting toilets, Panya Project, Thailand

Sizing the chamber

There is no real practical limit on the size of this kind of toilet. At the Panya Project, we built a Humanure toilet with space for four separate toilets as using adobe bricks and a concrete panel floor. Using cement or similar unnatural material for the floor is recommended so the moisture from the chamber doesn't erode the floor.

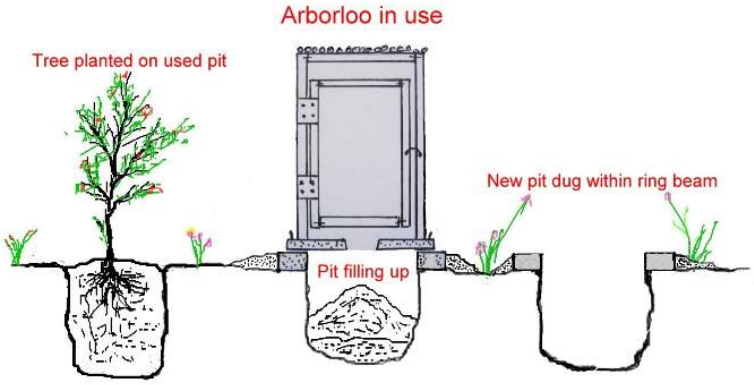
The composting chambers in the toilets pictured above are 3m x 2m x 2m, totaling 12m3. One year after the toilet was opened, with about 20 people using them on average, the chambers from the two operational stalls were still not full. A 12m3

chamber may be too large. 4m3 may be a more reasonable size. More research is underway.

One common design of a "Humanure" toilet, by Joseph Jenkins author of *The Humanure Handbook*, is to place a 20L bucket underneath a composting toilet. Variations of this design would include a larger container to be placed under the toilet. Another design option is to add a flue to the poo chamber. This will allow moisture to escape and help the pile break down faster.

Arborloo

An arborloo is a movable composting toilet. First, dig a hole about 1m^3 deep. Then set a lightweight, movable frame on top of the hole and build lightweight walls for privacy. Make your poo deposits. Once the hole fills up, move the frame to a new hole, mix the feces with soil and plant a tree on top. As human waste decomposes and becomes less toxic over time, it will provide good nutrients for the tree. Arborloo's require no moving of human waste, just mixing it in the hole.



www.memoireonline.com/02/07/348/sanitation-in-urban-peri-urban-areas-cap-haitien-social-marketing-approach.html

Solar Composting Toilet

You can also install a solar collector to the side of the poo chamber. The collector will capture heat during the day and channel it to the poo pit, this will also help speed up the process of decomposition.

Urine Diversion (UD) Toilet

Urine and water do slow the decomposition time down in a dry composting toilet. A urine diversion-composting toilet diverts urine into a separate hole or container. You can dilute urine with water, at a 1:10 ratio, and use on plants. You can also add **wood vinegar** to get rid of maggots and improve the smell of the poo chambers.

Human Waste Composting Pile

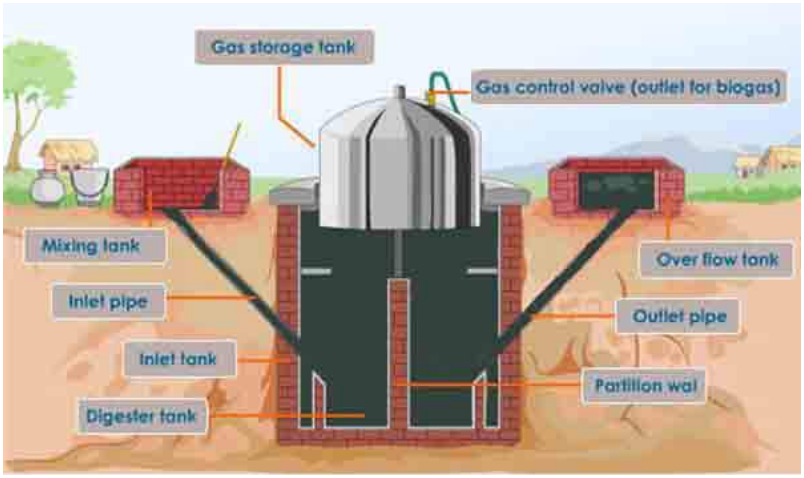
A human waste composting pile is a remote compost pile to decompose feces into fertilizer. The process calls for two waste areas. Line the bottom of both bins with a layer of plastic and a few inches of soil. The first bin should be mixed with sawdust, lime and any other drying agents you can get your hands on. Turn the pile at least once a week. Once the pile has aged for a few months, the feces loses its toxicity and can be transferred to the second pile. The second pile is to be inoculated with good soil from where it will likely be used. This pile should also be turned at least once a week. After a few more months, the soil is good, healthy fertilizer. Total composting time: about six months. Note: This area should be separate from your organic compost pile.

Flush Toilets

Flush toilets use a lot of water, about 4-20 liters per flush. Usually flush toilets are connected to a septic tank and a drainfield. This system can work well if the water is recycled into a garden, and you have access to enough water to continuously operate a flush toilet.

Bio-digester / Bio-gas system

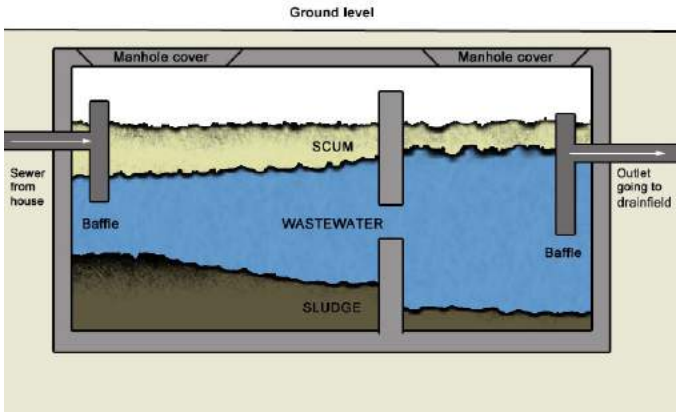
A bio-digester is large plastic sack for human and animal feces. The system has an input tube for feces and two outputs. One output directs methane gas to a cook stove. The other output directs feces to a container to hold bio-slurry. There are several types of bio-digesters. Here is a one found on Appropedia:
http://www.appropedia.org/HSU_Chiapas_biodigester.



Bio-digestor detail - www.thebiooasis.com/biodigester

Septic Tank

A septic tank is connected to the drainpipe of a flush toilet. Septic tanks are commonly designed with two chambers. In the first chamber, most of the waste solids sink to the bottom. When the first tank fills up, water spills into the second tank. The second tank provides a second area for solids to sink. When the second tank fills up, the overflow water runs out of the tank into a drainfield. Septic tanks need to be emptied when they fill up, so be sure to install a way to remove the solid waste. Look online for schematics and calculations.



Common design of a septic tank

Drainfield

A drain field is a place for septic tank runoff, as well as grey water (shower/laundry/kitchen drain) runoff. A drain field

consists of connected perforated PVC pipes sloping at a slight downward angle. Long trenches need to be dug, lined with plastic then filled halfway with gravel. Lay perforated PVC pipe midway up the trench then fill the rest of the trench with gravel. Then plant non-edible plants above the gravel. As black and grey water trickle through the perforated PVC pipe, the water will be used to grow non-edible plants. Here are some instructions on how to build a drainfield: http://www.ehow.com/how_5039124_build-septic-drain-field.html.

Soil

Principle: Build healthy soil

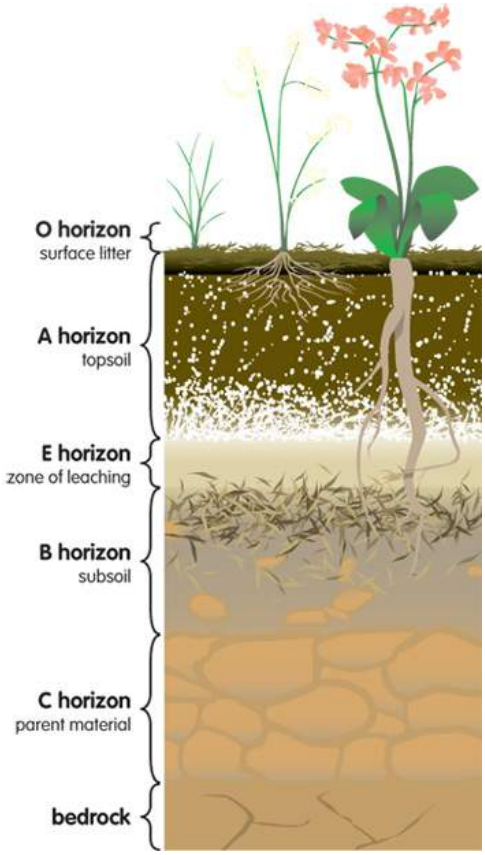
Compost piles, Panya Project, Thailand

Soil is the upper crust layer of earth where plants grow. Typically soil is a dark brown material consisting of a mixture of minerals, organic matter, air, water and a myriad of microorganisms that support plant life. Soil performs several important functions: it is a medium for plant growth, a means of water storage, supply and purification and a habitat for millions upon millions of microorganisms.

Plants and animals aid in the development of soil through the addition of organic matter. Fungi and bacteria decompose this organic matter into a semi-soluble chemical substance known as humus. Humus is the final stage of soil decomposition. Humus enhances a soil's ability to hold and store moisture, is the primary source of carbon and nitrogen required by plants for their nutrition, it improves soil structure, which is necessary for plant growth. Larger soil organisms, like earthworms, beetles, and termites, vertically redistribute this humus within the mineral matter found beneath the surface of a soil.

Soils are strong when they are diverse. Add different types of organic matter to increase the soil's resiliency to disease. As your soil matures, fungal nets will grow around the roots to physically protect plants from disease carrying organisms.

High food production starts with good soil. If your soil has good percolation, a good smell and good structure, you have good soil. With good soil, you have good nutrient uptake, resistance to disease, high water retention and strong microbial life. With good soil, you can grow food.



Soil Horizons

The layers of the earth look like this:

0 horizon – Surface, leaf litter
A horizon – Topsoil, humus
B horizon – Sub soil
C horizon – parent material
Bedrock – Rock / Minerals

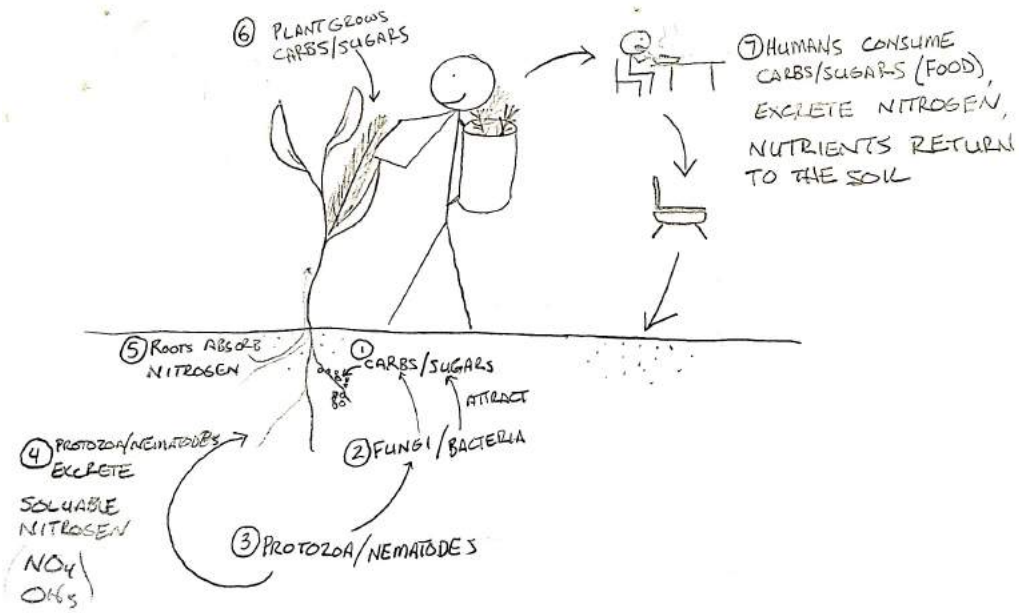
Soil food web

A plant, like a person, needs food. Plants eat nitrogen. Plants evolved to pull soluble nitrogen from microorganisms in the soil. The soil food web is a whole system designed by plants to pass nutrients to their roots, their shoots and eventually to their fruits.

How the soil food web works

1) The plant produces exudates secreted through pores in the roots. Exudates are carbohydrates and sugars released to attract microorganisms.
2) This attracts bacteria and fungi to eat the sugars and carbs, respectively.
3) Some bacteria and fungi are consumed by the plant.
4) Protozoa and nematodes consume the rest of the bacteria and fungi in the soil
5) Protozoa and nematodes release NO3 (nitrite) and NH4 (ammonium) as waste products, two forms of soluble nitrogen for plants.
6) Nitrogen can now be consumed by the plant.

The plant then produces carbs and sugars as vegetables and fruit. Convienently, humans come along and pick and eat the vegetables and fruits. They then create humanure, which over time turns into a soluble nitrogen to be consumed by the plants. Through this symbiotic relationship, plants are the great communicators between humans and the soil.



Soil food web

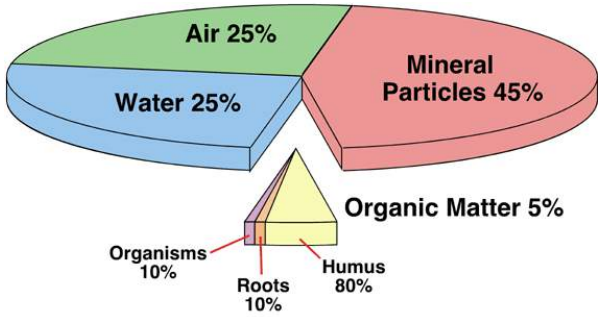
Note about chemical fertilizers: Chemical fertilizers are comprised of mainly three elements: nitrogen, potassium and phosphorus. While these three elements do comprise the main ingredients in plant food, these fertilizers don't provide all of the trace elements found in good soil. Over time, the lack of these nutrients causes the soil to lose fertility.

Soil composition

Physical composition

Soil typically consists of (note these figures range widely):

- 25 % Air
- 25 % Water
- 45 % Minerals (sand, silt and clay, from eroding rocks)
- 5 % Humus (decaying organic material, provides nutrients)

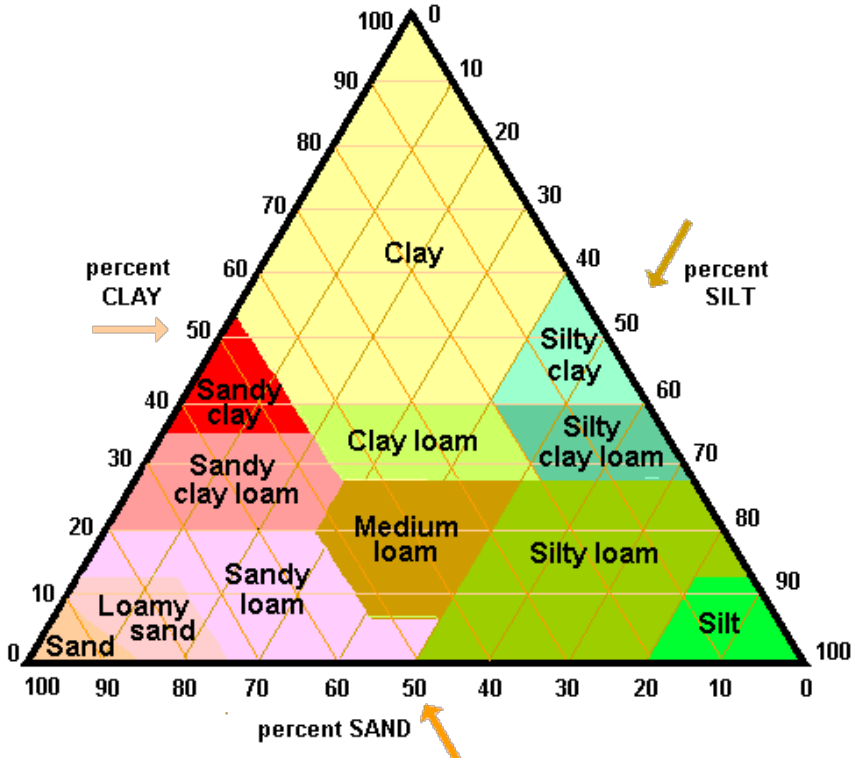


Soil composition

Dirt composition

Soil is composed of clay, sand, silt particles. The best garden soil has: 30-50 % sand, 30-50 % silt, 20-30 % clay, although this figure varies.

Soil textural triangle



Soil textural triangle

Soil nutrients

Building blocks:	C + HO
Major:	N, P, K
Minor:	Ca, Mg, S
Trace:	Fe, Mn, Zn, Cu, B, Cl, Mo
Minor trace:	Cobalt, strontium, vanadium, silicon, nickel

What the nutrients provide

Building block nutrients:

C – Carbon is the building block of all life. Plants absorb Carbon in the form of CO_2, mostly through their leaves. A plant's weight is about half carbon.

H – Hydrogen (water)
O – Oxygen (air, water)

Note: All nutrients except carbon, hydrogen and oxygen are absorbed by the roots of the plants.

Major nutrients

N – Nitrogen. Builds green matter, leaves, etc.

- Fixed into the soil from legumes and lightning
- Added by manures and decomposed animal and plant matter
- Abundant in the soil, often in the form of raw organic material which cannot be consumed directly. See *soil food web* to read how the plant creates soluble nitrogen.

P – Phosphorus. Helps build flowers, fruits and seeds

- Comes from fish, fish meal, seaweed, bird manures
- Some plants can fix it, casurina and some palms
- Mycorrhizal fungi help the plant to get this nutrient

K – Potassium. Helps build roots and adds to plant health

- A number of plants mine it
- Pot ash (ash from citrus and brassica)

Minor nutrients

Ca – Calcium, Strengthens cell walls

Mg – Magnesium, Aids in the uptake of phosphorus
S – Sulfur, Helps form proteins and chlorophyll, essential to plant vitamin synthesis

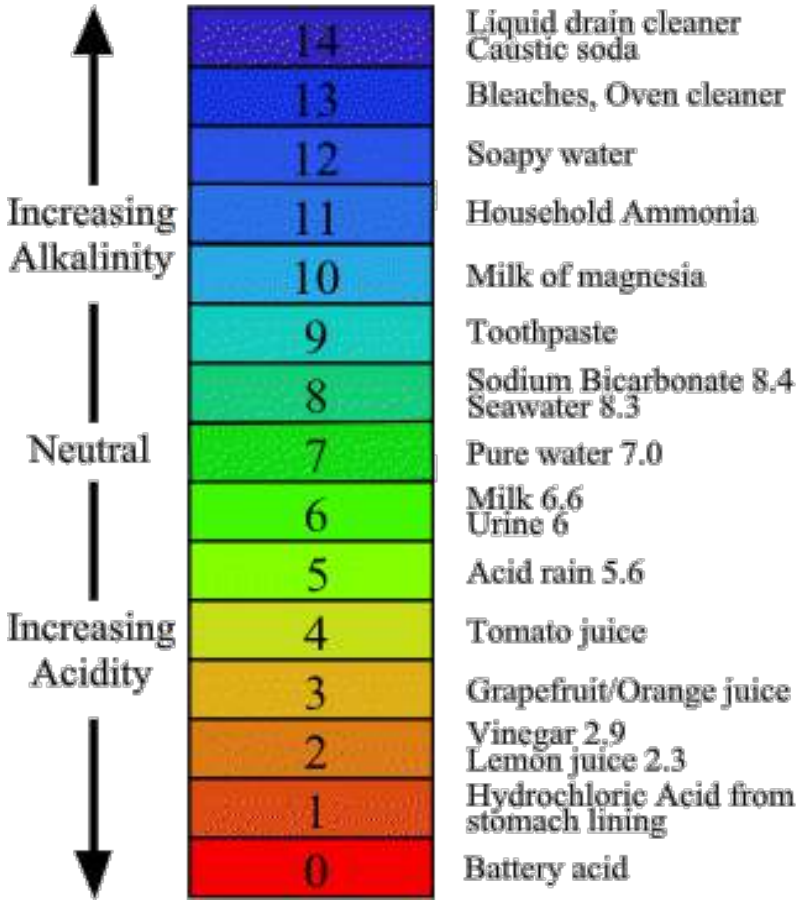
Trace nutrients
These micronutrients are required in very small amounts but are essential to plant health. When soil lacks these nutrients, it becomes degraded:

Fe – Iron
Mn – Manganese
Zn – Zinc
Cu – Copper
B – Boron
Cl – Chlorine
Mo – Molybdenum

Minor trace nutrients enhance the health of a plant:
Cobalt, strontium, vanadium, silicon, nickel.

pH

pH means "power" of hydrogen, derived from the German word *Potenz*. The pH can affect the availability of nutrients in the soil. The pH indicates how easily roots can absorb the elements in the soil, or the dissolvability of nutrients in water. pH is measured using a scale – 0-14:



pH scale

www.sites.google.com/site/theamazingwondersofsoil/the-source-of-soil

Plants prefer soil at a pH of 5.5-7.5. Some (strawberries, potatoes) do prefer more acidity, some plants prefer more alkalinity, 7 or below = Humid plants, 7 or above = arid plants.

0	Battery acid
2	Lemon juice
2.5	Coca-cola
4	Tomato juice, wine
4.5	Acid rain
5	Black coffee
5.5	Normal rain
6	Urine
7	Blood, water
8	Seawater

8.5	Baking soda
9	Cement, caustic chalk
10	Milk, soft soap
12	Bleach, ammonia
13	Lye
14	Drain cleaner

Fixing pH

The easiest way to fix soil with the right pH is to add one ton of compost and spray with 20 liters of compost tea per acre. If your soil is too acidic (0-6), add lime, sea shells or bones. At 4.5 pH certain toxic heavy metals, like lead and mercury become soluble in water. If it falls any lower and aluminum becomes soluble, plants die. If it is too alkaline (8-14), add sulfur, pine bark or woodchips. Organic matter always adds nutrients and neutralizes the pH of soils.

Measuring pH

There are a few ways to measure pH:

- Litmus test, thin strips of paper with a testing kit. Blue = alkaline, red = acidic.
- pH kits, similar to the ones used for swimming pools.
- Submit soil samples to any local agricultural university for lab testing.
- Plant hydrangeas – the color of the flower reflects the pH of the soil.

Compost

Making a compost pile, Mango Tree, Nepal

Compost is decayed or decaying organic matter. Composting speeds up the process of the soil food web. Inoculate the soil with a broad diversity of microorganisms (MOs). And add structure and diversity to the soil – Good compost can have billions of fungi, bacteria and microorganisms, which help retain micronutrients.

How to make compost

The ideal carbon to nitrogen ratio is 30:1. For every part of nitrogen consumed by a plant, the plant consumes 30 parts of carbon. To determine an appropriate C:N ratio, you can add the C:N ratio of each added component listed below.

Composting materials

Carbon (brown material), 50%

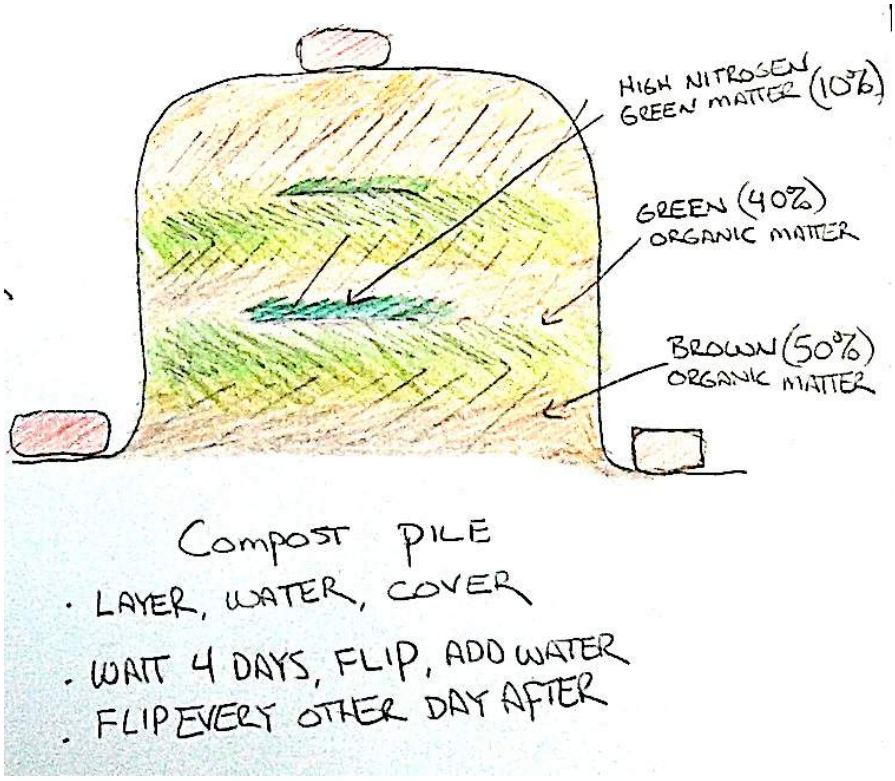
Wood chips, sawdust, shredded cardboard, shredded paper, straw (shredded), pine needles, cornstalks (shredded), brown leaves.

Nitrogen (green material), 40%

Fruit waste, nut shells, weeds/fresh cut leaves, fresh hay, food compost, grasses, seaweed, humus (local soil), manure

High nitrogen (green), 10%

Urine, fish or animal carcasses, biogas slurry, manure, coffee grounds alfalfa, pond plants, worm tea, manure, plant matter/legumes, eggshells



Methods of composting

Short-term compost pile

You can make beautiful, rich healthy soil in just a few weeks when you make a short-term compost pile. This method is also called 18-day compost, Berkeley compost or thermophilic compost. This compost heats up and breaks down organic material relatively quickly. Each layer should be 10-20cm thick.

Making the pile

When making a short-term pile, it's good to use material thinner than your index finger. This will enable the material to break down quickly. A typical compost pile is 1–1.5m^3. This is to make it easy on yourself when you turn the pile. If you have more material to add, you can extend the pile in any one direction.

Layering – Make each layer 10-20cm inches thick. After adding each later, add a lot of water. Add local soil as well to inoculate pile with indigenous microorganisms (IMO).

Covering – Cover with a tarp to maintain moisture (In wet climates, cover it to protect from getting too wet. In dry and hot climates, cover it to keep from drying out.)

Flipping – Turn the pile after 4 days. Then turn the pile every other day for two weeks. A pitchfork works well to turn the pile. Take the outside and turn it to the middle so every bit of compost gets time in the heat. *Note:* After 4 days if the pile heats up, a white fungus will grow in the middle of the pile. This means the process is working. This fungus eats pathogenic microorganisms.

Checking for moisture – Grab a handful of compost and squeeze. If a few water drops run down your wrist, you're in good shape. That's about 50-60% moisture content. Add water accordingly.

Checking the temperature - Each time you flip the compost, stick your hand in the middle of the pile. If it is too hot to keep your hand there, the thermophilic process is working. You can also use a thermometer. If temperature is above 50ºC starts to kill weed seeds and harmful MO. Ideal pile temperatures are 55-65º C.

Long-term compost pile (Huglekultur)

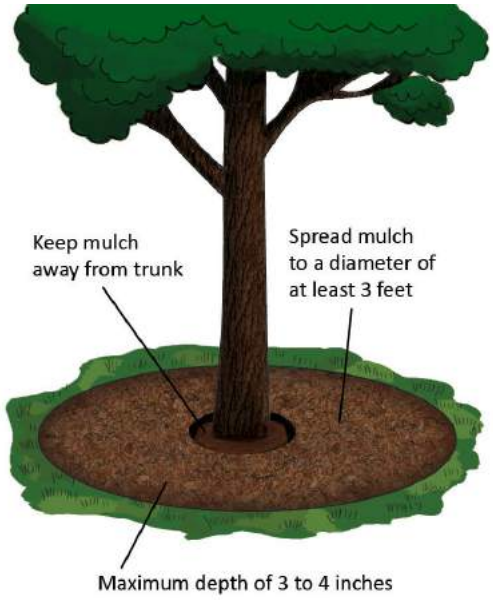
A long-term compost pile uses thicker sticks and branches. Thick branches are thicker than your index finger. Anything smaller than that will decompose within a few weeks. When you start the pile, add a thick pile of sticks and branches to the bottom layer. This increases air flow to increase oxygen to the pile. Depending on the size of the pile and the materials used, this pile can take 6-12 months or longer to break down.

Raised bed huglekulture, From Sepp Holzer's Holzer Permaculture

Applying compost

Whether short-term or long-term compost, once the soil has broken down, add compost directly to the base of trees and throughout your garden. It is best to apply on a cool part of the day. Always add mulch for shade protection – you don't want direct sun on your compost or soil.

Mulch



www.tnlandscapedesign.wordpress.com/2012/02/19/make-up-for-your-garden/

Mulch is organic material spread around vegetation to enrich, insulate and retain moisture in the soil. Nature already mulches itself. For example, trees create the perfect conditions themselves by literally growing a thick layer of their own detritus. Mature forests have a thick layer of mulch on the ground (especially temperate forests). Mulching provides many benefits:

- Reduced competition from weeds by blocking sunlight
- Retains moisture
- Regulates temperature
- Over time, mulch breaks down into soil

These benefits create:

- Increased nutrient uptake by the plants
- Ideal habitat for microorganisms, which attract insects and lizards, which attracts frogs and birds, which attract mammals
- More diverse and healthy soil food web

Mulch materials

Here are some good mulch materials: Dried leaves, straw, cardboard, sawdust, wood chips, used clothes (cotton or other natural materials), newspaper, branches (chop and drop).

Note:

- You can use green matter, but beware of it getting too thick and matted, as it will start to compost and create heat, which can damage new roots.
- Avoid putting rocks in your mulch. Rocks work great as a garden barrier, but the rocks can heat up in the sun and damage new root growth.

Methods of mulching

Chop and Drop

The chop-and-drop method is when you chop down fast-growing pioneer (ideally nitrogen-fixing) plants for mulch. Because these trees grow very fast you can chop the whole tree down. It's best to allow the shade to fill in before the dry season. Shade is more beneficial in dry times. Legume trees like leauceana, glycidia, pigeon pea, acacias are good chop-and-drop types of plants. There are many.

Coppicing, pollarding and pruning

These are ways to trim a tree for healthy growth and create good mulch material. More on these sections in *Trees and Forests*.

Mulching around trees

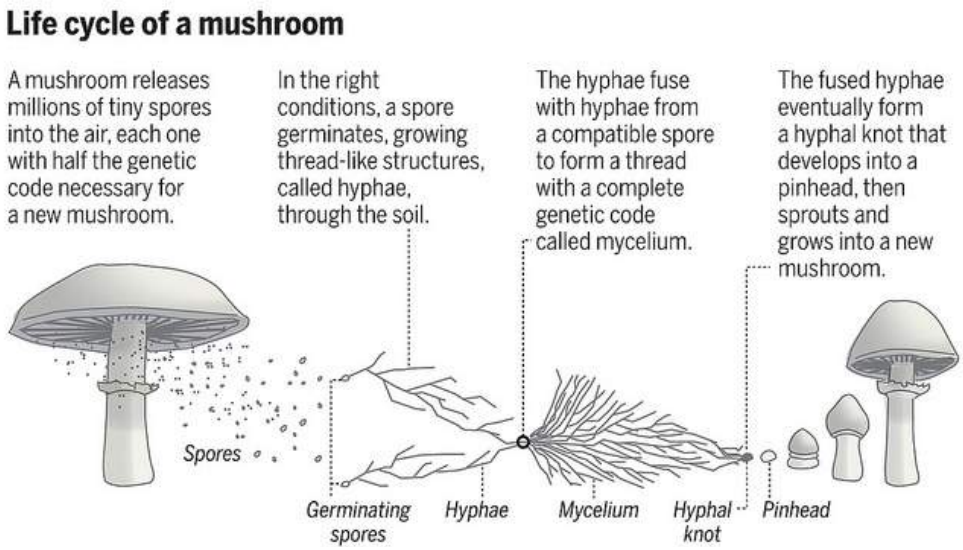
The root structure of trees goes out beyond the drip line of the canopy, so mulching as much of the area as possible under a tree is good. Mulch in a donut shape around the trunk of the tree – leave some space around the base of the tree to prevent rotting. Let the tree breathe.

Fungi

Fungi are unicellular or multi-cellular spore-producing organisms feeding on organic matter. Fungi include molds, yeast, mushrooms and toadstools. Fungi feed on decaying organic matter.

Mycelium is the vegetative part of a fungus, consisting of a large underground network of fine white filaments in the soil. Mycelium builds soil very fast by gripping the soil and retaining moisture.

Mycelium transfers minerals over long distances to supply trees and plants with nutrients, as if to aid the process of succession.



Life cycle of a mushroom, www.allaboutmushrooms.com

Mycorrhizal fungi

These fungi have beneficial interactions with the roots of plants. Mycorrhizal mushrooms consist of some of our favorite wild edible mushrooms like chanterelles, porcini, truffles and matsutake. 95% of plants have beneficial relationship with “the mighty mycorrhizal” fungi.

Growing Mushrooms

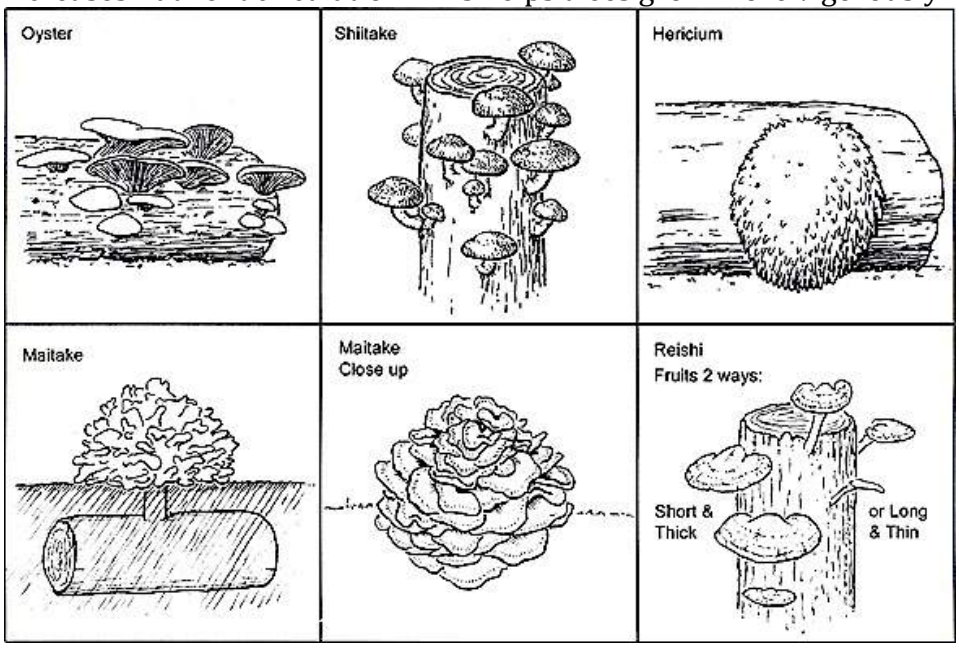
Mushrooms thrive in areas that are grassy, wooded, damp and moist. Here are a few methods for growing mushrooms outside:

Indigenous microorganisms (IMO1)

Leave cooked rice in a wooden box, 7cm thick. Leave it in the woods buried in dirt for 1 week. A white fungus will appear, called Indigenous Microorganisms 1 or IMO1, according to some. Add to your compost pile. This can be used as a starter for other fertilizers.

Tree inoculation

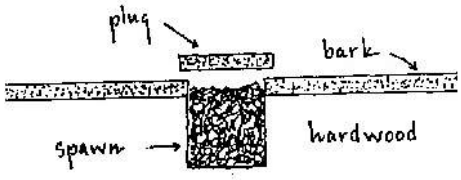
Inoculating trees with mycorrhizal fungi when they are saplings increases nutrient circulation. This helps trees grow more vigorously.

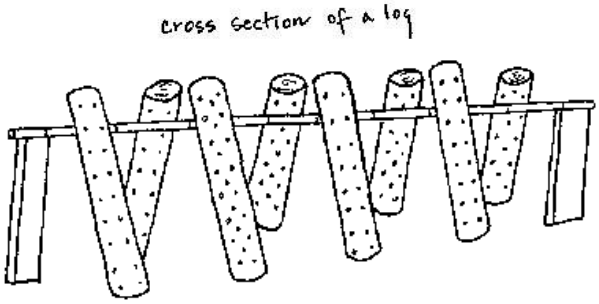


www.mushroomadventures.com/t-dowel_spawn_instruction.aspx

Growing on logs

- Drill holes in a freshly cut log, every 15 cm or so.
- Drop a few mushroom spores in each hole and plug with sawdust
- Keep the logs in wet environment at all times. Try soaking them in a pond. You can't soak the logs enough.
- After one year the log should start producing and produce for years





http://bit.ly/1F8tq5d (www.nzdl.org)

www.realfarmacy.com/growing-shiitake-mushrooms-is-easier-than-you-think

Growing mushrooms in bags

It is common in Thailand and India to grow mushrooms in plastic bags. Each bag is filled with sterilized rubber tree sawdust, then inoculated with mushroom spores and sealed. Each bag will produce 3-5 batches of mushrooms. Plan wisely or else you will have heaps of mushrooms all grow at once.

Mushrooms in bags, Sapney Farm, Auroville, India

Bio-remediation

Mycologist guru Paul Stamets (author of Mycelium Running) once took a piece of wasted land covered with oil spills, toxic waste and gasoline saturated soil. He first inoculated the soil with mycelium. He arranged three tests piles and a control pile. After four weeks, hundreds of pounds of oyster mushrooms came from the land. After more time, insects came, plants came, and life returned. The control had little growth. This process is called bioremediation – using biology to improve a piece of land.

Microorganisms

Indigenous microorganisms (IMO1) grown from cooked rice
Kailash Akhara, Thailand

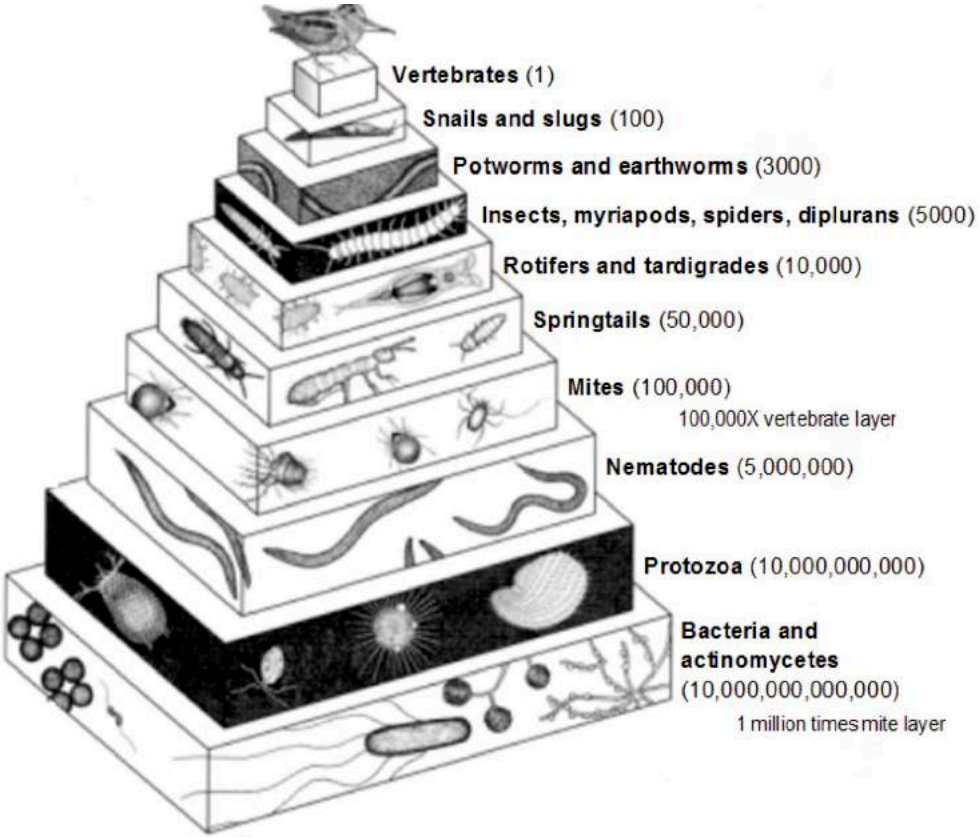
Indigenous microorganisms (IMOs) live in the soil, water, air and forest. They are everywhere. We can collect these organisms to inoculate our soil with the local mini-beasts.

Effective microorganisms (EMOs) have many benefits to soil fertility and all stages of the plant growth process, from seed to fruit. By adding EMOs in the form of fertilizers to your soil, it increases the fertility of the soil, which increases the amount of nitrogen, the food for the plants.

Natural fertilizer recipes sourced from Natural Farming by Arnat Tancho from Maejo University, Thailand. Many thanks Dr Tancho and his team for this research.

Organisms in the soil

Soil is teeming with life. In $1m^2$ of healthy soil, there can be:



Organisms in one square meter of soil

Natural fertilizers

Preparing fertilizers is a good, cheap and easy way to increase the microbial activity and make more food for your plants. Listed below are types of fertilizers you could make to increase plant growth, sugar levels, repel insects, provide deficient minerals among many other benefits for your plants. The benefits of each fertilizer are listed in parenthesis below. Following are the recipes for how to make each EMO solution:

Rocks or gravel (natural mineral)

How to make: Smash rocks to increase the surface area exposed to the water (locally available or purchased gravel), Put small pieces of rocks inside some of the mesh bag or wire basket, Fill container with water, when adding water pass through a mesh bag filled with IMO3, Add seawater diluted 30 times to increase minerals. **Benefits:** Cures diarrhea in livestock, Increases health and drought tolerance of plants.

Cooked rice (Fungus, IMO1)

How to make: Place 7cm fresh cooked rice in a wooden container. Don't press the rice. Cover the box with dirt and leaves for 1 week. After 1 week, white fungi will appear on the surface of the rice. Called Indigenous Microorganisms, or IMO1, as referenced in the *Natural Farming* book. **Benefits:** Add to compost pile to speed up microbial activity. This indigenous microorganism agent can also be used to inoculate other IMOs.

Sugar (IMO2)

How to make: Add sugar or molasses to a portion of IMO1. Mix thoroughly. Sugar slows down activity and is food for MOs. Cover with cloth. Keep in dry shade. **Benefits:** Improves soil fertility

Fresh plants (hormones, nutrients, lactic acid, MOs and yeast)

How to make: Pick leguminous plants before sunrise, Chop into small pieces. Add sugar at ratio of 3:1 in a container, Fill container 2/3 full with water, Cover and place a rock or heavy object on top of the mixture to force out any air, Leave to ferment for 20-30 days . Add IMO1 or 2. Keep in a dark cool place. **Benefits:** Increases beneficial microorganisms to plants.

Legume plants (potassium)

How to make: Grind or pound the plants thoroughly, put in a clay container, add 100 liters of water to 2-3 kg of ground material, cover with cloth, leave to ferment for 20 days in a cool dry area with no direct sunlight. **Benefits:** Stimulates photosynthesis, increases sugar and starch content in leaves, improves yield quality, crop weight and sugar content.

Animal compost (protein)

How to make: Place fish or animal bones and meat in container. Add sugar. Leave for 1 week. Add IMO2. **Benefits:** Stimulates microbial activity. Contains nitrogen, phosphorus, potassium, calcium and magnesium.

Rice (fermented rice water)

How to make: Soak uncooked rice in water (brown rice if available), cover with cloth. Keep in cool, dry place for 1 week. **Benefits:** Nourishing formula for seeds, promotes stem and leaf growth and flowering, increases resistance to insects and bacterial diseases, can absorb more nutrients.

Milk (lactic acid bacteria)

How to make: Add milk to rice water, 10:1 (water: milk). Leave for 1 week. The yellowish layer on the bottom is lactic acid bacteria. That's what you're looking for. This liquid can be kept for a long time.
Benefits: Dissolves and absorb natural elements and attach them to soil particles. Promotes stem and leaf growth and increases resistance to fungi disease.

Eggshells (calcium)

How to make: Dry eggshells in sun, then smash them into small pieces, add 10 L of rice water and 2 liters of wood vinegar, leave to ferment for 9 days. If bubbles appear during fermentation (from reaction between fermented rice water and shells) add crushed shells until the bubbles stop. **Benefits:** Increases sugar levels of fruit if added just before harvest.

Fruit (hormones and enzymes)

How to make: Put fresh fruit and roots in a bowl. Fill 2/3 full. Add sugar. Layer the fruit varieties according to sugar content. The sweetest fruit goes on the bottom. Cover with cloth. Leave for 3 weeks.
Benefits: Strengthens plant development.

Roots (herb hormone, insecticide)

How to make: Soak roots in water overnight (roots such as ginger, garlic, turmeric, neem, derria root, eloptica, stamina are good). Pound thoroughly. Place in a clay container. Add molasses, rice wine or beer to cover the herbs. Ferment for 2-3 days. Add sugar and fill with water up to 2/3 full. Stir thoroughly. Leave for 4-5 days. **Benefits:** Used for nourishing plant seeds, also increases resistance to insects and diseases

Human urine (nitrogen and other nutrients)

How to make: Pee in a bucket, Add molasses or worm juice (equal parts) to get rid of the urine smell. Ferment for 21 days. Dilute heavily before using.
Benefits: Lots of nitrogen

Manure (magnesium and phosphorus)

How to make: First, air dry whatever combination of manures you have in the shade. Cow, horse, chicken and even human manure are good. Add 10 liters of molasses or 10 liters of wood vinegar per 1 kg of manure.
Benefits: Magnesium helps the photosynthesis process. Phosphorus builds cell nucleus which promotes flowering, increases sugar content in fruit and helps with carbohydrate transferring.

Rice husks (silicon)

How to make: Make a pile of 100 parts rice husks + 1 part ground up rice bran, Water the pile, keep moisture level at 60-70%, Cover with plastic and leave to ferment 4 months, After 4 months, the bottom of the pile is full of silicon and ready to be used.
Benefits: Used to strengthen cell walls of plants to resist insects and diseases.

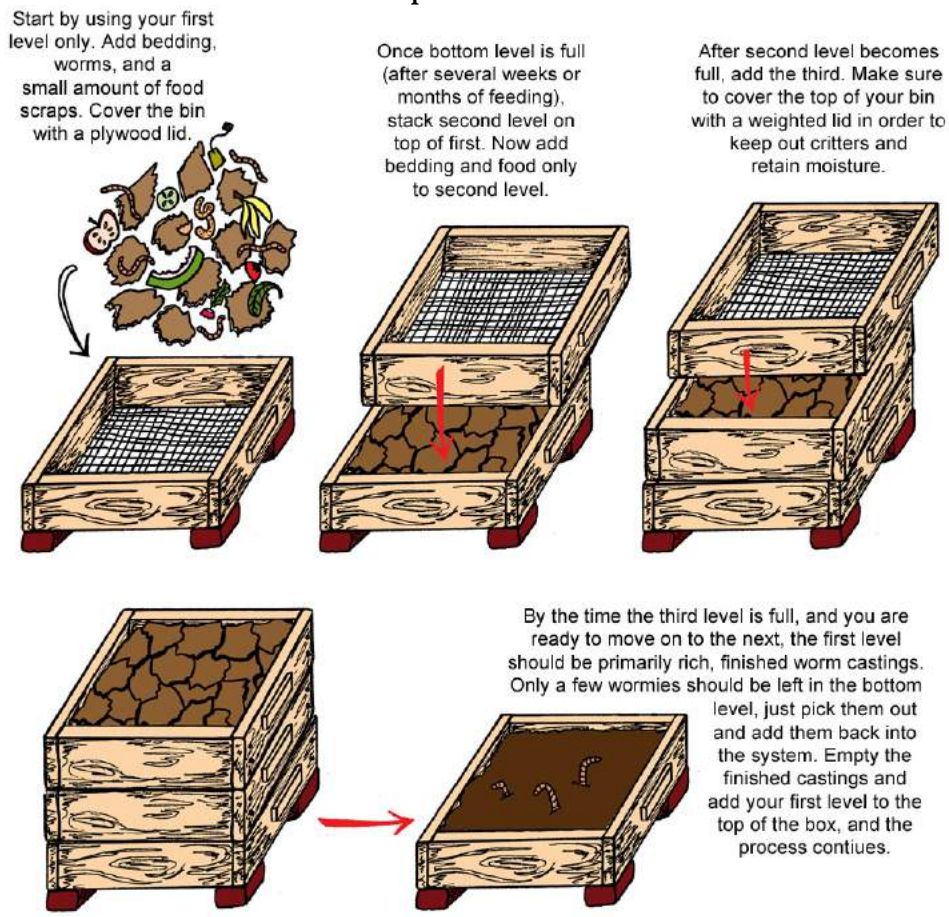
Worms

Red wriggler worms eat their weight in food every day and double in population every 40 days

Worms eat organisms in the soil and produce worm castings and urine (also called worm pee, worm tea or worm juice). “Red wrigglers” are a common type of worm used in permaculture. They are good for compost and propagate very quickly. 1 kilogram of worms = about 1000 worms.

To propagate worms, you can make a worm composting bin:

How to make a worm compost bin



www.homesteadnotes.com/make-a-worm-farm-for-your-homestead/2/
Some other good how-to's: www.sierra-worm-compost.com/building-a-worm-bin.html, halifaxgardennetwork.wordpress.com/2011/09/13/letting-someone-else-do-all-the-work/

What worms like to eat: Anything green, especially leafy greens, fruits, vegetables, coffee grounds and filters, tea bags, brown paper, black and white newspaper, crushed eggshells.

What worms don't like to eat: Citrus fruit peels (like orange, lemon or lime), fats, oils, salad dressings, breads and cereals (attracts gnats), sugars or processed food, meat, garlic or onions (creates odors) or salts – no seasoned food.

Feeding – Leave the food on top without mixing it in. Let the worms do the mixing. When the food is nearly eaten, add more. Just like compost, if it's too wet, add carbon (brown material), if it's too dry, add nitrogen (food scraps, coffee grinds). It's good to feed them a few times a week.

Keeping them in – The worms may try to climb out of the container at night. Leave ¼ empty so they don't climb out! Also try rubbing soap around the top inside rim of the worm container to keep them in. Or a good cover.

Moisture – Maintain 50-60% moisture content. You want water to drip down your hand when you squeeze it, like compost.

Castings and worm juice – How you harvest your worm castings depends on how you construct your bin. Generally speaking though, worms move toward food and leave castings behind. Add castings anywhere you have soil – garden, forest, compost pile. Dilute worm juice (actually worm pee) 20:1 and also add to soil.

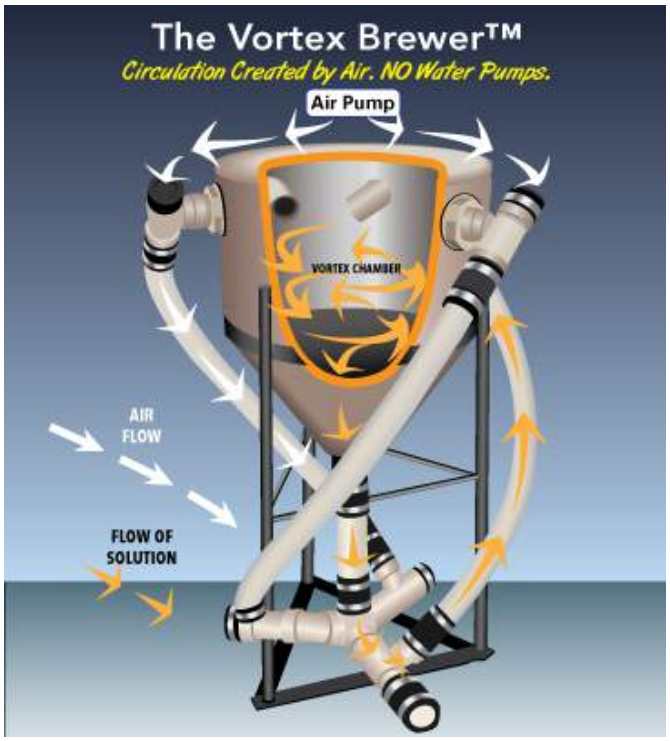
Compost tea

Compost tea is aerated compost liquid fertilizer. This is also called Actively Aerated Compost Tea (AACT). Liquid fertilizers are soluble, meaning it is easier for plants to consume the minerals.

How to make compost tea

The following method for making compost tea can work for any size and any system depending on your needs and interests:

1) Use 20L bucket, 200L drum, large tank or any size container
2) Fill container 10-20% with compost or compost materials - 2 parts carbon + 1 part nitrogen + high nitrogen additive). Fill 20-30% if using compost materials
3) Fill bucket/tanks ~80% full with water
4) Attach a 2-inch PVC pipe to an air pump, aerate the mixture from the bottom of the mix for at least 24 hours.
5) Use immediately
6) Mixture adjustments
    a. To increase bacteria content add molasses, cane juice, fruit juice or maple syrup
    b. To increase fungus add kelp, humic acid or rock dust



This compost tea brewer design, "The Vortex Brewer", aerates the tea as it spins around in a vortex motion. While the water moves in the direction of a vortex (or tornado) the water molecules expand and absorb nutrients from the compost. Go to www.vortexbrewer.com or look up "vortex compost tea brewer" on Youtube.

Compost tea application

You cannot spray too much or too often. Apply early morning or late afternoon, when the sun is not strong. Water on garden, leaves, trunks, soil and mulch, compost piles, toilets, even in ponds. For broad acre land, spray 20 liters compost tea per acre. It is good to give your garden a good soak at the beginning of rainy season. Microorganisms will flourish everywhere, and will find the appropriate place they can thrive and benefit the system.

Nursery

Principle: Save seeds

A nursery is a structure designed to help propagate and care for young plants. The structure also helps to save and store seeds and prepare fertilizers. It provides protection from heavy sun and rain and other weather while roots grow. You can plant plants or seedlings directly in a garden, however starting seeds in a nursery raises a plants survival rate.

Large agricultural companies have started patenting seeds reducing the number of available organic, local seeds all over the world. But at the same time, more communities are starting local seed banks and helping new farms get started. It is important for people have access to organic, heirloom seeds so we can continue the practice of farming.

The nursery seems to be the bedrock of the farm. A good nursery, leads to good immature plants, which leads to a more productive garden. Properly managed nurseries appreciate in value and help create surplus, and in turn, profit. With little up-front investment and consistent labor, the seedlings that mature in the nursery speed the growth of your own garden, and can be sold or given away to help start others.

Nursery elements

Greenhouse or Covered Grow Area

A greenhouse is a building in which plants are grown. In cold weather, greenhouses provide a controlled environment to grow plants. In more tropical areas, a covered grow area protects seedlings from heavy rains. Greenhouses provide a centralized place to start growing

seeds. Check out *Growing Under Glass* for a good reference to greenhouse construction.

It is good to position a nursery near a compost area for easy access to good soil. In cold climates, you can put your compost pile or even keep small animals, inside your nursery to retain heat in cold months.

Basic nursery table uses plastic mesh as the tabletop

Greenhouses can be any shape or size. One design is called a polytunnel or 'hoop house'. This dome shaped structure uses pvc, bamboo or other material to form a hoop or a tunnel. The structure is then covered with a sheet of plastic. Polytunnels can be 5-6m wide, 8-10m long, as a general reference for size.

Polytunnel design nursery, www.farminmypocket.co.uk/greenhouses-polytunnels/polytunnels-introduction/community-polytunnels

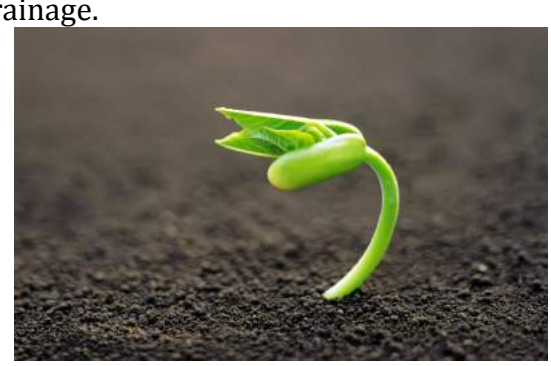
A geodesic dome is another type of shape, which can be modified to make a greenhouse. Go to www.desertdomes.com for a dome calculator.

Dome greenhouse
www.dixib.com/luxurious-green-house-dome-for-plants-made-from-wood-material-with-extraordinary-ornament/luxurious-green-house-dome-for-plants-made-from-wood-material-with-extraordinary-ornament-picture/

Potting Soil

Before you can plant, you will need potting soil. Potting soil is useful for cuttings (in bags) and sowing seeds (in seed trays). To make potting soil:

1) Dry sand and compost in the sun then use a screen or other fine wire mesh to sift the fine particles
2) Mix equal parts of sifted compost, sifted sand and humus (coconut fiber, sawdust, chopped straw, fine woodchips – mulch material)
3) Use more sand the smaller the seeds are.
4) *Note:* Do not use clay or ground soil in potting mix. Clay prevents drainage and ground soil is too mixed up. You want good drainage.



Fine, consistent potting soil provides a good environment to grow plants

Seed saving basics

Seed saving is a great way to develop seed-lines that are well adapted to a particular environment. Saving seeds from the healthiest plants year after year enables growers to select for traits that are most

suitable for their growing conditions. Following are the four basic steps to saving seeds:

1) Choose seeds to save

Plants can be divided into two types of pollinators: self-pollinated and wind/insect pollinated:

- **Self-pollinating plants**, like tomatoes, peppers, beans, lettuce, peas and broccoli are the easiest to save seed from because they rarely cross-pollinate. Self-pollinating seeds that are biennial crops, such as carrots and beets are harder to save since they need two seasons to set their seeds.
- **Wind or insect-pollinating plants**, including cucumbers, melons, corn, pumpkins, gourds, and squash. These plants readily cross-pollinate.

2) Collecting seeds

Some notes on collecting seeds:

- Take seeds from the healthiest-looking plants.
- Allow the seed to reach full maturity before collecting.
- Mature seeds usually have a hard seed coat or a darkened color.
- Once ripe, pick and dry the seed as soon as possible. Seeds contained in a pod or husk should be left to dry on the plant.

www.pinterest.com/buddhafarm/seed-saving-techniques/

3) Cleaning seeds

Seed cleaning methods can be divided into wet-processing and dry-processing. To clean wet processed seeds:

1) Cut open fruits and scrape out seeds. Place seeds, pulp and juice from the fruits in a bowl with a cockroach (yes) or other dead insect. The insect helps the seeds to ferment and eliminate seed-borne diseases that can affect the next generation of plants.
2) Place seeds in a large bowl or bucket. Rinse.
3) Add water and stir mixture. Good seeds will sink to the bottom, while poor quality seeds are more likely to float.
4) Pour the seeds into a strainer and washed under running water.
5) Dry the cleaned seeds by spreading as thinly as possible on a flat, dry surface such as a glass or ceramic dish, cookie sheet, window screen, or piece of plywood.
6) Shuffle the seeds a few times a day as they dry.

To clean dry-processed seeds:

1) Separate seeds from husk, flower head or pod. Seeds that are in pods, may need to be smashed.
2) Place seeds on screens with a wire gauge small enough to prevent seeds from passing through. Coffee filters allow for excellent air circulation.
3) Leave in the sun to dry. Make sure seeds are protected from wind and the elements. Source: smallfarms.oregonstate.edu/sfn/su09Seedbasics

7) Storing seeds

Once seeds have been cleaned and dried, place them into a clean, airtight container like a glass jar, plastic container or plastic bags. Leave in a cool, dark place. Make sure to label all seeds. Basements or refrigerators are good locations – the colder the better. You want an environment that keeps seeds dormant – note: opposite conditions to what is necessary to make them grow (webgrower.com/information/save_seeds.html).

Storing seeds in jars and labeling them keeps them dry and organized

What is plant propagation?

Propagation is a method to rapidly multiply plants. Plant propagation maintains the genetics of seeds. There are two general methods of plant propagation:

1) Sowing seeds – Sexual

- *Benefits:* Grow many plants, less chance of transferring disease, gives opportunity to select traits, transport
- *Drawbacks:* Takes a long time to mature, not true to the type
- Propagating tips: Sow seeds **2-3x deeper** than width
- For very small seeds, mix with sand to apportion into seed trays
- Beans, peas, pumpkin seeds – plant directly into the ground

Buying seeds: Check out these organic seed online distributors to start your own garden or nursery: www.SeedsofChange.com, www.Seedman.com, www.Seedshop.com, www.Seedsnow.com, www.Botanicalinterests.com, www.Seedsavers.org.

2) Vegetative – Asexual (cloning)

- Benefits: True to type (exact replicate, clone), reaches maturity faster, propagates plants that are difficult to grow from seed.
- Drawbacks: Needs more space, transfers disease easier

Cutting

Some types of plants can be propagated by simply cutting and replanting branches. First, find a decent sized branch. Look for a branch between the size of a pencil and the size of your index finger. It's good to cut a branch at least 15cm long, or you can cut a long branch and make additional cuttings from that. Cut on an angle, just below the node, the place where a new stem grows. Leave 1-2 leaves when you cut the branch. Paint the tip with honey to stimulate growing. Replant in moist compost immediately.

Here are a few examples of plants you can propagate by cuttings:

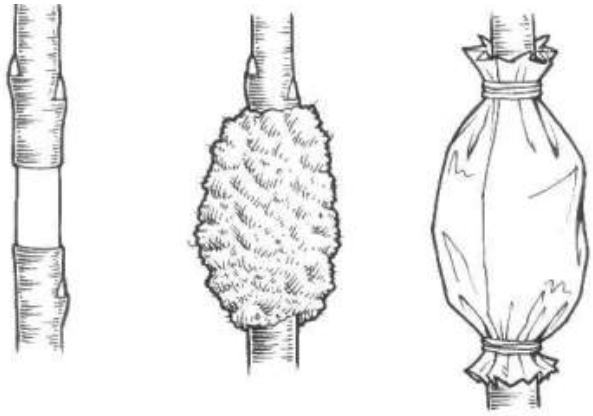
- Root (guava, breadfruit, comfrey)
- Leaves (succulents, Brazilian spinach)
- Soft-tip (softwood, pinto peanut)
- Brown/green branches (hardwoods, lucaena, mulberry, taro)

Layering

Air layering

Air layering is a form of propagation where you wrap a plastic bag filled with compost on a tree and sprout new roots in the air. Mulberry trees, among other types of trees propagate via air layering. To properly air layer a plant:

- Find a branch you want to air layer, choose a branch about the size of your finger. Find an internode, the place on the branch between nodes (nodes are where new branches grow)
- Slice the outer layer of bark about 5cm long, peel away the bark
- Wrap the exposed wood with compost at 50% moisture, coconut husk, moss and or clay, wrap in a plastic, then in aluminum foil to not let in light, tie ends of bag
- Let grow for 8-10 weeks or when roots poke through the foil
- Cut the new branch just below roots, replant immediately

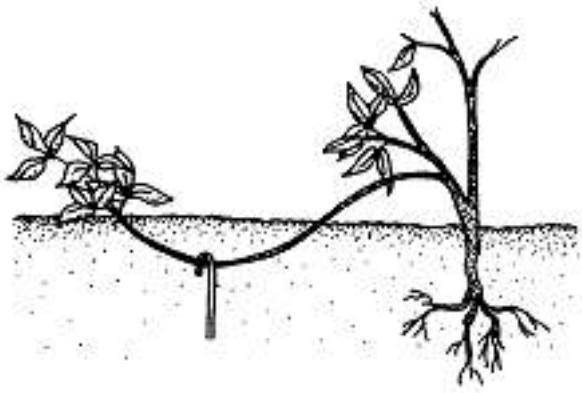


Air layering (you can use compost instead of moss as well)
hortipedia.blogspot.in/2011/07/how-to-air-layer-shrubs-trees-woody.html

Ground layering

Ground layering plants send runners through their drooping branches that climb along the ground and shoot roots into the ground. This type of layering can be done on most plants with low-growing branches. Some examples of ground layering plants include climbing roses, forsythia, rhododendron, honeysuckle, boxwood, azalea, and wax myrtle. Ground layering can be accomplished by:

- Bending a low growing, flexible stem to the ground. Cover part of it with soil, leaving the remaining 15-30 cm above the soil,
- Bend the tip into a vertical position and stake into place. The sharp bend will often induce rooting.



Ground layering

Division

Here are steps to propagation by division:

1. Dig the plant up when flowers have faded,
2. Shake the soil from the roots,

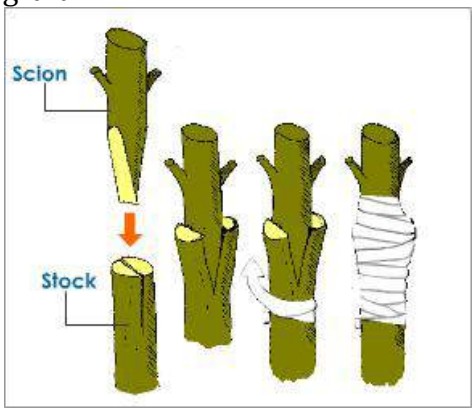
3. Break the plant into several pieces at the nodes or between leaves. The important thing is to make sure each divided piece has shoots and roots on it.
4. Replant immediately in good soil in a pot or sheltered garden bed and water thoroughly.

Here are a few examples of plants that propagate by division:

- Runners –Pull apart and plant (grass, mint, strawberry)
- Suckers – Pull and plant (succulents, banana, cactus)
- Bulbs/korum – Pull apart and plant whole (garlic, onion, tulips, taro)
- Rhizome/tuber – Plant directly (ginger, turmeric, galangal, potato)

Grafting

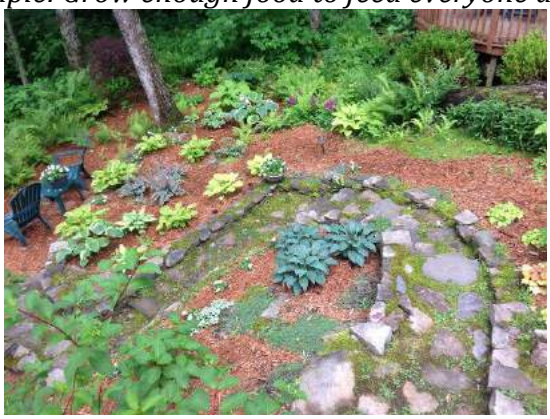
Grafting is another way to propagate plants. It is a bit more complicated, so do some research. Below is a sketch of how to do a particular type of graft.



V-grafting technique (typical)
www.tutorvista.com/content/biology/biology-ii/reproduction/cloning.php
Other types of grafting methods can be found here: blog.ub.ac.id/puspitt/page/2

Garden

Principle: Grow enough food to feed everyone at site.



Home garden, Highlands, North Carolina, USA

A garden is a space reserved for the cultivation and enjoyment of plants. Gardens provide food for people and food for the soil, nutrition, nourishment, awareness, education and fun. While many gardens grow ornamental plants, permaculture gardens focus on growing edible crops.

There are many aspects to consider when designing and planting a garden. This includes the location, shape, bed, soil and structures. Then once you plant your garden, companion planting and crop rotation are useful techniques to grow a large harvest.

Garden site location

Consider these aspects when designing and planting a garden space:

1. **Natural conditions** – Consider the wind, aspect, climate, edges, slope, sun, soil conditions
2. **Access to water** – Water points, grey water pond runoff, wicking beds. *Note:* Gardens with good, healthy soil need to be watered less. Sometimes 1-2 times a week versus 2-4 times a day *(*ref. *Symphony of the Soil)*.
3. **Access/pathways** – Think about how you will physically harvest food
4. **Garden elements** – Consider the garden's proximity to the nursery, greenhouse, tool shed, animal structures and compost pile

Ollas are clay pots, fired or sun-baked, used to store water and keep soil moist for a long period of time. The water slowly wicks out of the pot over several days. This conserves water and keep the soil damp.

Ollas vary in size.

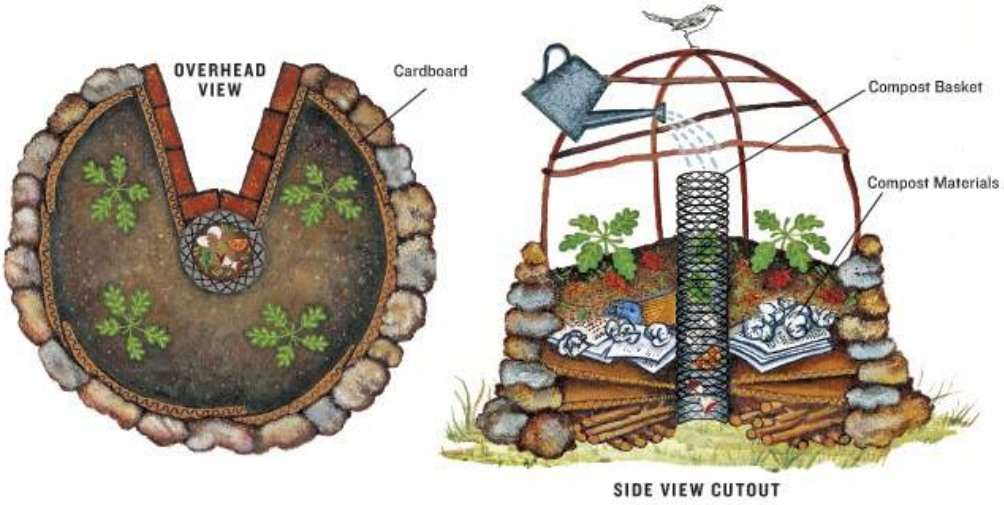
Burying the ollas

Covering with dirt
Photos from Urban Homestead
www.urbanhomestead.org/journal/2008/03/24/using-ollas/

Garden shape

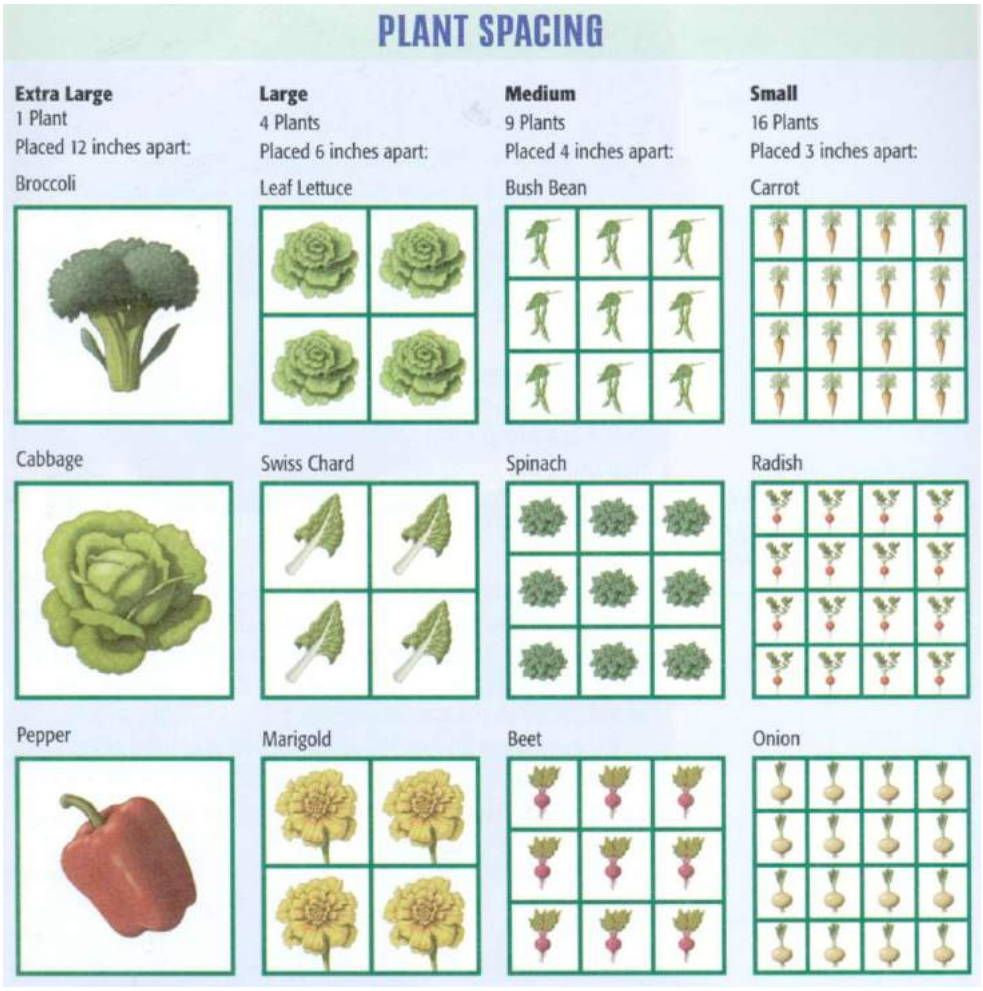
Once you choose a location to plant your garden, now you can decide what shape you want your garden. Here are a few ideas:

1. **Keyhole garden** – A keyhole garden is built in the shape of a circle measuring about 1.5m in diameter. The garden stands waist-high and has a hole in the center for compost that moistens and nourishes the soil. (http://www.texascooppower.com/texas-stories/nature-outdoors/keyhole-gardening/). You can include several "keyholes" in the shape of a mandala.



2. **Square Foot Gardening –** This technique divides a raised grow bed into square foot sections and makes it easy to keep track of what you planted. Designed by engineer Mel Bartholomews, SF gardening makes it easy to keep track of what you are growing and have a simple crop rotation and higher output with the efficiency. Ref: All New Square Foot Gardening.

Square foot gardening 4' x 4' box



Garden design for Square Foot Gardens

(Source: The All New Square Foot Gardening book)

3. **Herb Spiral –** An herb spiral garden is for growing edible and medicinal herbs. A good dimension for this type of garden is about 1 cubic meter, but it can be any size. The height creates small microclimates. These microclimates allow different herbs to grow. To build: Stack rocks in the shape of a spiral, starting in the middle and going down. Then fill all of the gaps with organic materials. You can plant your herb guild as follows:
    - Starting at the center, at the highest point, plant rosemary then spiraling downward plant dill, oregano, thyme, chamomile, Echinacea, sage, yarrow, fennel, chives, parsley, coriander, calendula and feverfew

Making a garden bed

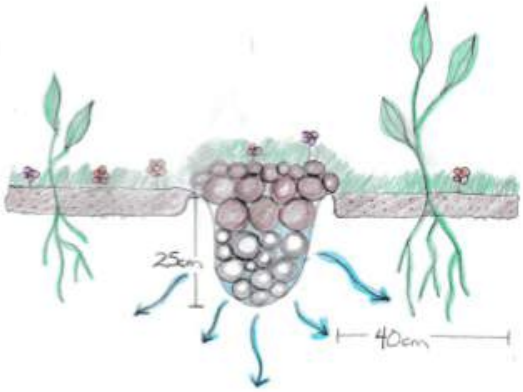
Here are a few types of garden beds:

1. **Raised bed** – Use rocks, glass bottles, bamboo, straw or other material to create a small rise (about 15cm). Fill the space with soil. This is a good technique for making a garden if the topsoil is hard. Let the roots break the soil.
    a. **Prepare and level the ground.** Clear or chip the ground with a hoe to flatten the space. **Plow**, if you want. Add compost and fertilizer to the soil as you break it up to enrich the soil. *Note:* Plowing does disrupt the ecosystem of the topsoil. Some people prefer to sheet mulch on top of the soil and allow the roots to naturally penetrate the hardpan layer.
    b. **Sheet mulching –** Find whatever organic material you can find and layer it like compost: brown, green, high nitrogen – on top of the soil. 10-30 cm high. Sheet mulching is also called lasagna gardening or composting-in-place. Over time, the layers break down into soil. You can do this right where you want you plant your garden.

Sheet mulching, as described by Toby Hemingway in Gaia's Garden

2. **Hugelkulture** – Large raised bed created by large (up to 1m) long-term compost pile beds (also known as **Hugelkulture**, using wood thicker than your finger).
3. **Sunken bed** – Good for water retention in arid/desert climates.

Raised bed hugelkulture, www.richsoil.com/hugelkultur/



Sunken hugelkulture trench design

Garden structures / vertical gardening

Ideal for the urban gardener. There are many techniques you could utilize to grow food indoors.

- **A-frames or teepees** – These are simple structures to allow vine plants to grow upwards. As the plants grow they create shade. Shade is helpful for growing other plants.

Vertical growing structure, Kailash Akhara, Thailand

- **Arch, wooden or woven wire trellis** – Arches are good for building over small streams or for pathways. They provide shade for plants growing next to water.
- **Tire stack** – To grow potatoes in tires, start with one tire. Fill with soil. Plant 3 or more potatoes. When those sprout and send runners above the soil, add another tire on top, fill it with soil and add more potatoes. Repeat for 6-8 tires, up to 1.5m.

Continue watering, when ready, knock off tire by tire and harvest.

Potatoes poking through the soil in tires
www.gaeasboxofrocks.blogspot.in/2009/05/growing-potatoes-in-tires.html

- **Indoor examples** – Window boxes, plastic bottles, vinyl sheet with pockets, hangers, hanging planters, railing planters, container gardening.

Plastic bottle garden wall *Palette herb garden*
http://betterfarm.blogspot.in/2012/09/growing-up.html

Once you've prepared the soil, you're ready to plant your garden:

Companion planting

A good plant guild strengthens each of the plants in the guild by providing nutrients, regulating temperature and water absorption rate. A good rule of thumb when deciding on which plants to grow together is **if they taste good together, they grow well together**. Here are a few annual crops that grow well together:

- Pumpkin, corn and beans (Three sisters guild)
- Tomato, garlic and basil (Pizza guild)
- Sweet potato and taro (For rocky soil)
- Cucumber, beans, peas
- Carrot, onion, cabbage, lettuce
- Chiles, sweet pepper, tomato

Annual versus perennial

Annual – Completes life cycle in one growing season, needs to be planted at the beginning of each growing season. Life cycle of an annual plant: Plant the seed, plant grows, flowers, sets seed and dies. Examples – corn, wheat, rice, lettuce, peas, watermelon.

Perennial – Lives for more than 2 growing seasons. Examples – squashes, broccoli, taro, potato, leek, strawberry.

Bi-annual – Takes two years to complete its biological lifecycle. In the first year the plant grows leaves, stems and roots. In the second year, the stem of the plant elongates or "bolts". The plant then flowers, producing fruits and seeds before it finally dies.

Garden succession

One trick to grow an even harvest of crops is to stagger the timing of when you plant them. For example, plant a few seeds of one crop one day, then two weeks later plant a few more seeds of the same crop. Keeping a chart helps of what you planted when helps to stay organized. This way you don't get a huge harvest all at once.

Crop rotation

Crop rotation is a method of growing a series of different types of crops in the same area in sequential session. This helps to balance soil

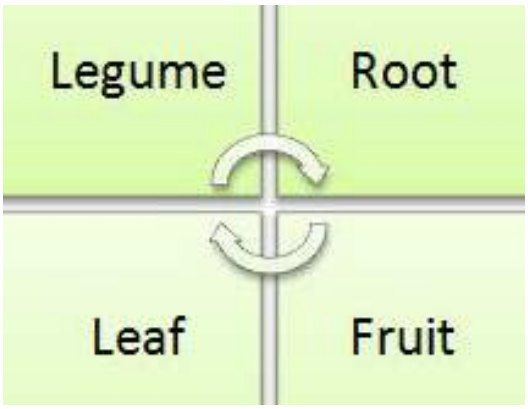
fertility and prevent diseases and pests. The sequence is logical – legume, leaf, root, fruit – Legumes add nutrients to the soil. Leaf crops consume some nutrients, root crops consume a medium amount of nutrients and then fruiting crops consume many nutrients. In which case, the next thing to plant is legumes and add nutrients back into the soil. Here are some examples of each type of crop:

Legumes – Nitrogen fixers
Peas, beans, lentils

Leaf – Light feeders
Lettuces (leeks, kale, bok choy, spinach, chard)
Herbs (dill, fennel, basil, parsley)
Brassicas (cabbages, mustard, turnips, cauliflower, broccoli, brussel sprouts), chives, celery

Root crop – Moderate feeders
Carrot, potato, onion, garlic, radishes, turmeric, beetroot, sweet potato, taro

Fruiting crop – Heavy feeder
Tomato, strawberry, peppers, cucumbers, pumpkins, squash, corn, eggplant



www.betterhensandgardens.com/garden-crop-rotation-a-simple-system

Trees and Forests

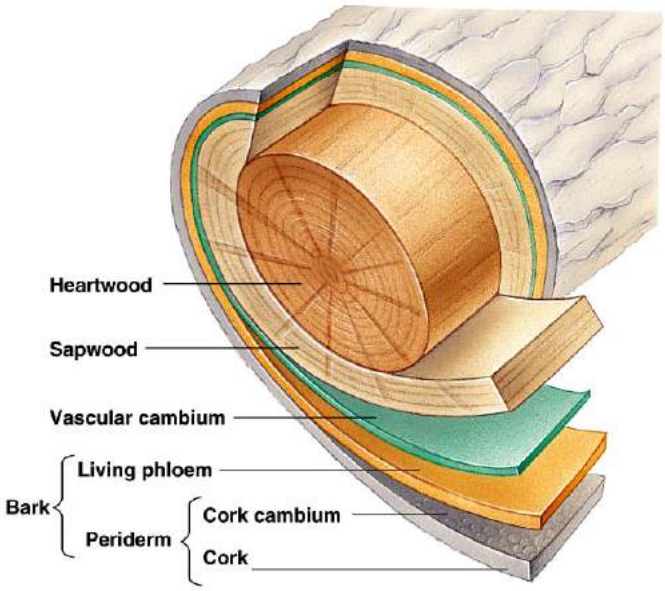
Principle: Plant useful trees

Bodhi Tree, Kailash Akhara PDC, Thailand

Trees are a central point of a forest ecosystem. They are productive, stable, self-maintaining, self-regulating, clean air-producing, water-storing, temperature-moderating, fertility-increasing organisms. Trees also:

- Provide habitats for other creatures, from microorganisms to monkeys,
- Insulate snow from melting and thus secures a water source for a longer period of time,
- Create transpiration. An ordinary elm tree will evapo-transpirate up to 15,000 liters of water on a clear hot day.
- Absorb rainwater. When it rains, water falls through the canopy, into the trunk and into the humus. After contact with each of these organisms, water accumulates microorganisms and soaks into the soil.

Trees embody the philosophy of permaculture. As Bill Mollison says, “without trees, humans could not inhabit the earth.”

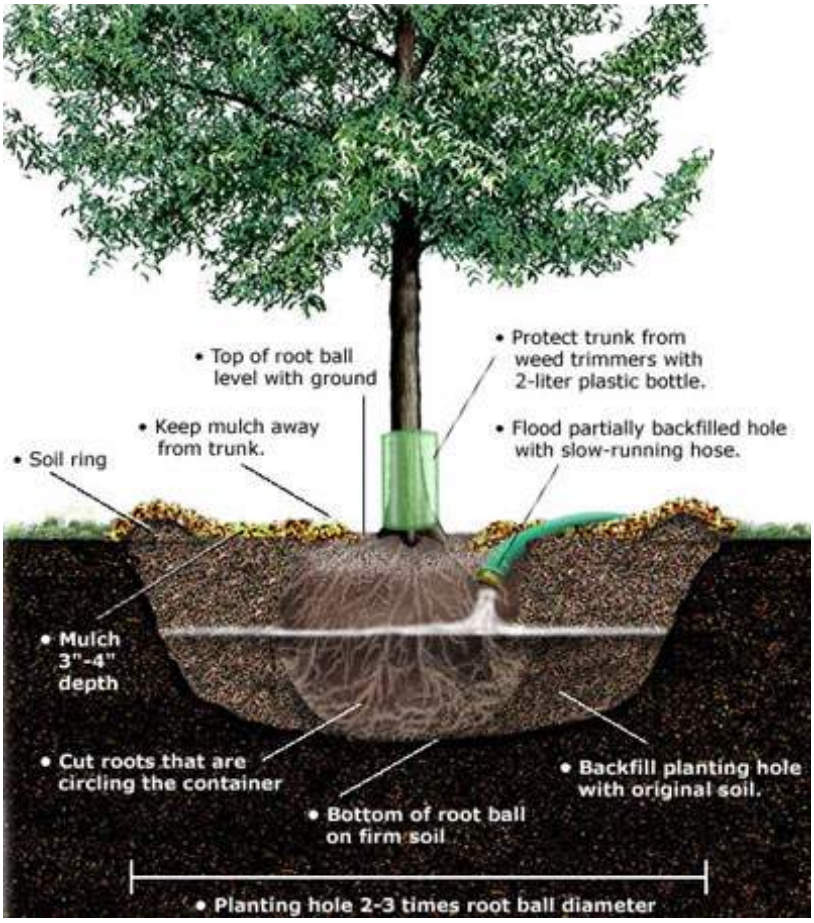


Layers of a tree, Source: Pearson Education Inc

Planting trees

There are many methods for planting trees. Here is one:

1. Dig a hole twice as deep as the root base
2. The hole should be in the shape of a wok, slightly rounded at the bottom to collect water. At the bottom of the hole, you can add coconut husks, banana leaf plates or other dense organic material.
3. Set tree. Add 3-4 handfuls of compost depending on the size. Mix compost with the removed soil, adding less and less compost the closer to the top. This introduces the existing soil with the compost and will help the tree to establish a root system.
4. Cover the whole area with mulch, avoid putting mulch directly next to the trunk.
5. If on a slope, add a berm to the top-side of the hole to catch rainwater. Water will seep into the ground above the tree and provide water to the roots. Or, as mentioned in the earthworks chapter, you can dig a fish scale swale at the bottom. Water will soak into the soil and encourage roots to grow deep.



Good tips on planting trees
www.dynamicscapes.com/services/landscaping/flower-beds-plant-tree-installation/#4

No-till tree planting

This procedure allows tree roots to penetrate the hardpan and not disturb the existing soil ecosystem (practiced at Sadhana Forest, India):

1. Select tree sites and water the ground for 2-3 days before planting to loosen the hardpan.
2. Once soaked, place a large 12" wide PVC pipe where the tree will be planted. Build a mound of soil around the PVC and make a berm on the upper side of the slope using the existing soil.
3. Inside the PVC, fill a layer with humanure and compost 50:50. Then place the tree and fill the rest of the PVC with mixed compost and existing soil.

Wick irrigation technique

One method to water trees throughout the day, also practiced at Sadhana Forest, is to turn a 2L plastic bottle into a slow-release watering system:

1. Cut a small hole the size of the wick in the bottom of the bottle.
2. Push in a cotton wick and leave about 20 centimeters outside the bottle. Seal with wax or silicone.
3. Fill the bottle with water and crack the top to let only the tiniest amount of air into the bottle. This technique could stretch 1L to last a week, a good amount of water required for a tree-taking root.

Photo credit: Sadhana Forest, India

Forests

A forest is a large area of land covered with trees or other woody vegetation. Forests are the dominant terrestrial ecosystem on Earth. Forests contain 80% of the Earth's plant biomass. Forests have many yields. Some of these yields include food, fuel, fiber, fertilizer, fodder, pharmaceuticals (farma) and fun.

Succession

Succession is the process by which an area undergoes more or less orderly and predictable changes following disturbances or initial colonization of a new habitat. To understand forest growth and thus how to design a forest, we need to understand succession.

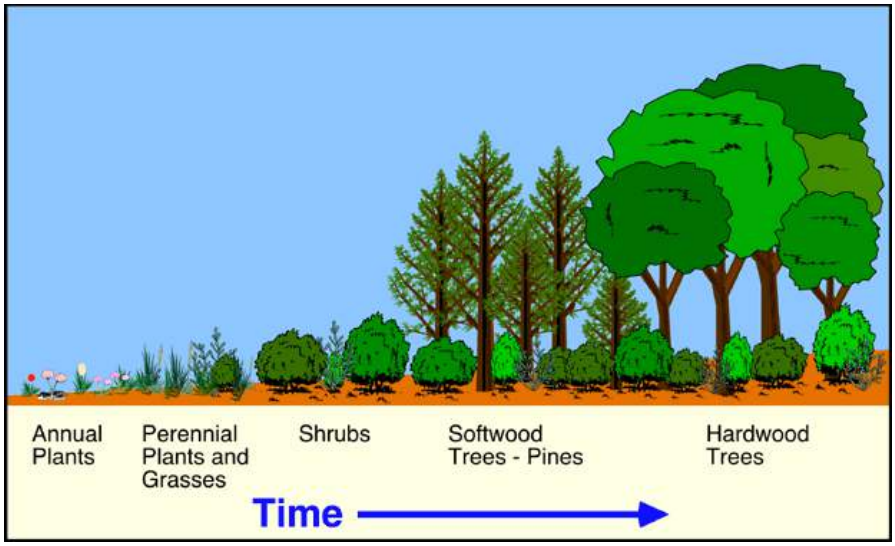
Primary Succession

This stage begins with barren rock or mineral substrate. Weather breaks down the minerals of the rock. Then bacteria, lichens, algae and mosses grow on the bare rock. This layer can last hundreds, thousands or even millions of years.

Secondary Succession

Once vegetation arises from the substrate, an area enters secondary succession. Succession generally advances in a similar pattern:

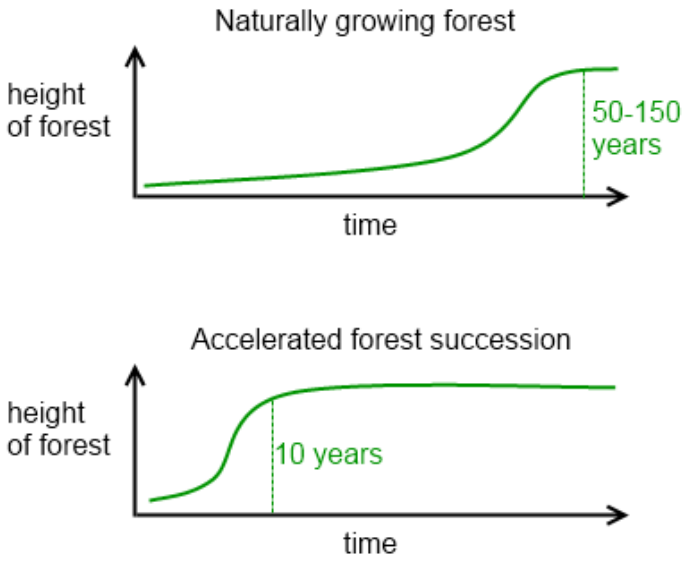
- Annual herbs and perennial plants – Grasses and herbaceous plants
- Shrubs – Woody weeds which are thorny to protect soil
- Understory trees – Creates shade for the new ecosystem
- Climax trees– Mature forest



Succession
www.physicalgeography.net/fundamentals/9i.html

Accelerating succession

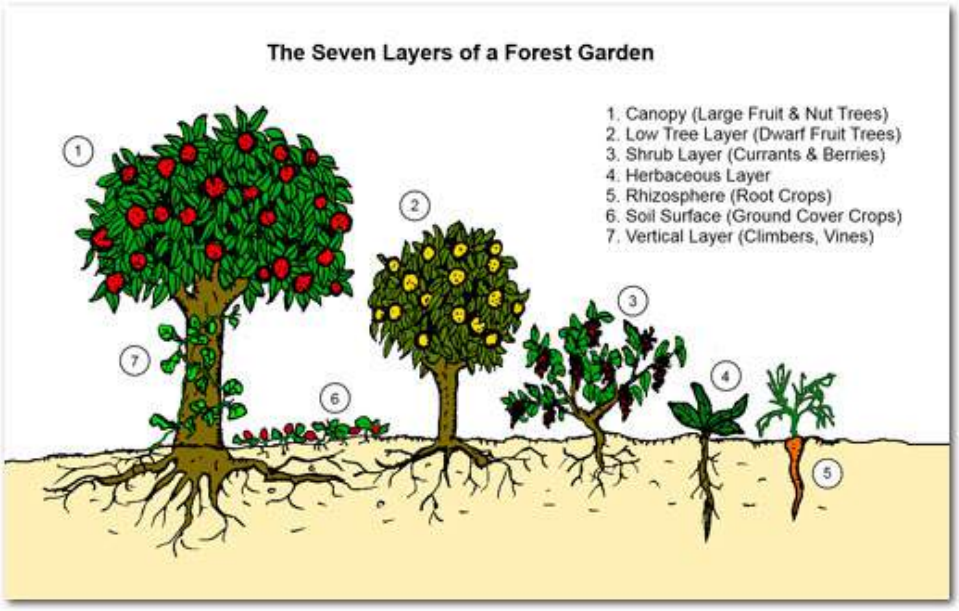
Forests take decades, even centuries, to mature on their own. But humans accelerate this process to establish a forest in less than a decade.



Accelerating succession
www.deepgreenpermaculture.com/permaculture/permaculture-design-principles/8-accelerating-succession-and-evolution/

Layers of a forest

In a mature forest, there are many types of vegetation thriving and growing and living and dying and becoming forest mulch. By observing the different layers of a forest, we can more effectively and more rapidly grow forests. The seven common layers of a forest are listed below. There are variations of this list. Some people consider root crops as a layer. Others consider the forest floor as a layer. It doesn't really matter how you define it – it's important to understand there are different layers. And we can plant these layers to recreate succession and accelerate the growth of a forest.



7 layers of a forest
www.pinterest.com/pin/560979697309148993/

Canopy (including emergent layer) – Typically 8-12 meters tall, canopy trees range from timber trees, nut and fruit trees.

Understory layer– Typically 3-9 meters tall. This layer consists mainly of shorter trees. Some are young trees, but others are trees that grow slowly because they didn't get enough light filtering through the canopy. The majority of fruit trees fall into this layer.

Shrub layer – Typically around 3 meters tall, the shrub layer includes mature shrubs and bushes, fruiting bushes, flowering, medicinal and other beneficial plants as well.

Herbaceous layer – The herb layer is typically small, perennial plants. Many perennial, culinary, medicinal and other beneficial plants and herbs are in this layer.

Groundcover layer – Groundcover layer crops are often shade tolerant, grow much closer to the ground, grow densely to fill bare patches of soil and often can tolerate some foot

traffic. The groundcover layer includes soil surface crops and nitrogen fixers.

Vine or climbing layer – Vines span multiple heights depending on how they grow. They are a great way to add more productivity to a small space. It is important to keep them trimmed so they are easy to harvest.

Mycelia or Fungal layer – Fungal networks in forest soils are nutrient and communication highways. Their health is inseparable to that of a forest garden. Unlike other soil life, we can sow, manage and harvest products from fungus.

Support species

Support species plants are good to plant near trees to provide nitrogen, keep pests away, attract insect among other benefits. Local areas will usually have several varieties of naturally growing legumes, groundcovers and insect attractors. Finding and planting those plants is a good strategy.

Legumes

Legumes can grow with little to no other vegetation. They colonize degraded land and "fix" nitrogen in the soil so it is more accessible for other plants. Legumes include nitrogen-fixing plants, dynamic accumulators and general pioneer species. Some say, legumes are the lungs of the soil, enabling other plants to breathe.

Ground cover

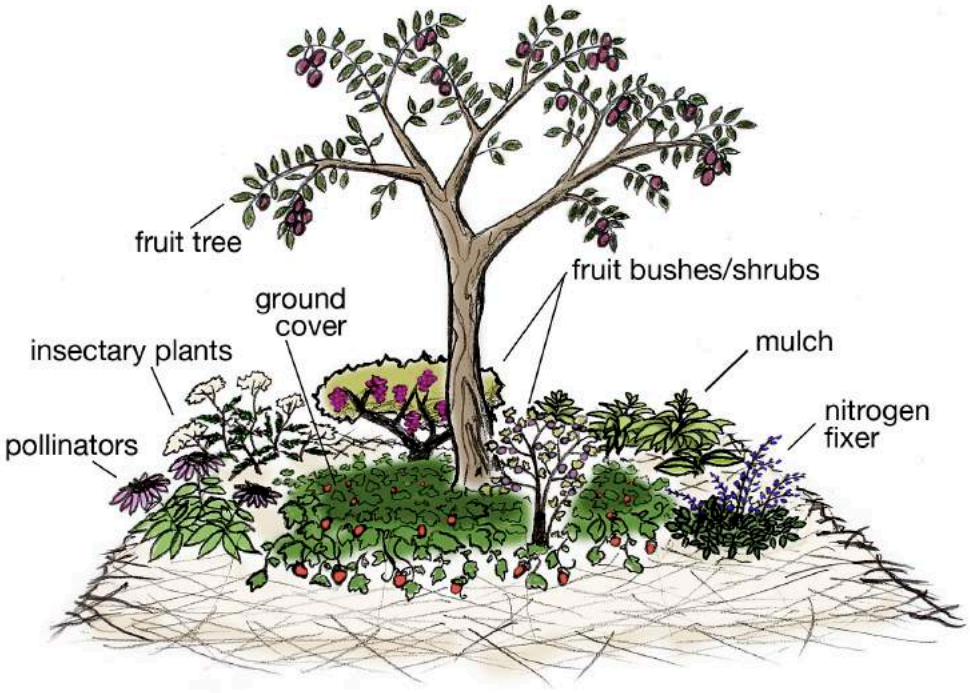
Groundcover plants protect soil from erosion and keep unwanted plants away. Groundcover plants include grasses, bulbs and some nitrogen-fixing legume plants.

Insect attractors

Typical insects attracted by these types of plants include lacewings, ladybugs, hover flies, tachinid flies and mini-wasps among other beneficial insects. These types of plants include flowers, aromatic herbs, salt tolerant flowers and other herbs and spices.
This will attract beneficial insects and repel unwanted aphids and insects from your plants.

7 support species: 1 tree species

A healthy tree guild will have 7 supporting plants for every canopy tree. Consider 7:1 as a rough estimate. Oftentimes you will be limited by the availability of plants, space or other resources.



A tree's support network
www.ecologiadesign.com/2013/04/05/food-forests

Food Forests

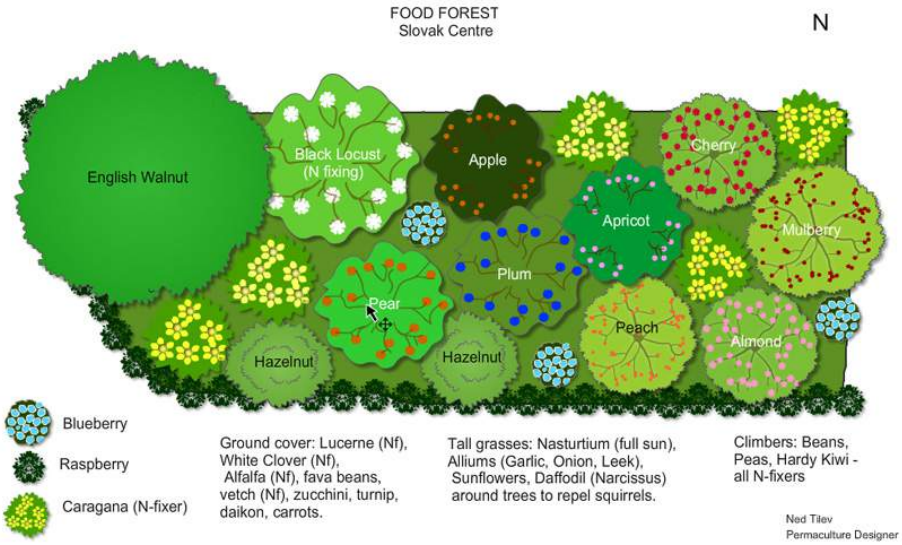
A food forest is a perennial polyculture of multi-purpose plants. It is a multi-year, multi-plant, multi-function forest. A food forest is a forest where most if not all of the species are edible or useful in some manner. Designing a food forest requires an analysis of different tree patterns and tree and plant species.

As a general rule, in the tropics you start with 90% legume trees, 10% fruit trees and 20 years later you have 10% legumes, 90% fruit. *Note:* You can plant up to 400 plants in a 6m x 6m area. As the plants grow, you can thin them out. It is easier to cut out than to plant later.

Planting a food forest

Here are a few guidelines for planting a food forest:

1. Earthworks – Do any necessary earthworks to prepare the land for water retention (See *Earthworks*)
2. Mulch – Of the existing organic material, deicide what to keep and what to compost. Make compost with existing brush. Mulch heavily.
3. Tree selection - When selecting a species, go to local nurseries to see what trees are available and grow well. Look around on your site. What trees can you air layer or take cuttings from to plant in your nursery? Go to your local organic market. Buy a bunch of fruit. Let it rot. Collect the seeds. Observe what grows. Consider what supporting plants and trees will grow in your area and be good companions to your canopy trees.
4. Design – It is helpful to make a sketch of the area you have to create a forest. Include paths, compost areas, benches and general patterns of tree designs you want to plant. Consider these shapes when designing your forest:
    a. Alley-cropping
    b. Island guilds
    c. Radial
    d. Scatter
    e. Intercropping
5. Observe – After the initial planting, observe your forest frequently (at least once a week after planting). Consider the following on these observatory walks:
    - Are the plants receiving enough nutrients and water? Is there damage or discoloration to the leaves? Are they being eaten? Which trees/plants are doing better than others? Why? Are they producing or starting to fruit?
    - Add mulch or compost – Adding 5-10cm of compost/mulch is like a fresh meal for the soil. Also add compost and mulch to trees 1 month before the rain starts and 1 month before the rain ends.



Food forest design
www.urbanfoodforestry.org/?attachment_id=395

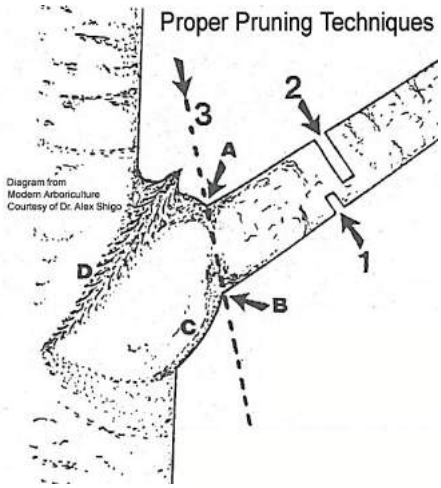
Coppicing

Coppicing is when you cut a tree back to its stump with the intention that it will sprout again. Coppicing is generally done to fix nitrogen in the soil, let more light into an area, encourage the plant to grow more thickly as in a living fence, or provide wood for mulch, firewood, fodder or building.

These methods are more efficient than replanting because the plant's root structure remains alive and in the soil. Coppicing can be done yearly or every ten years, depending on the climate and species. **Pollarding** is a similar technique where you remove the upper branches of a tree to promote a dense head of foliage and branches.

Pruning

Pruning is when you cut away dead or overgrown branches to encourage fruitfulness and growth. Here is an illustration of how to properly prune a tree and how to select what branches to cut. It's best to prune at the beginning of the rainy season to give trees the most time to recover.



Pruning techniques – Notch at 1, notch at 2, then cut through 3 from A to B
The notches, esp 1, allow the branch to fall cleanly.

Chop and Drop

Chop and drop is the process of "chopping" branches and "dropping" them on the forest floor. Leaves and branches slowly decompose over time and add nitrogen to the soil.

Aquaculture

Principle: Raise healthy fish and plants

Aquaculture is the name of any type of water or wetlands where water animals and plants are grown in support of each other. Ponds, chinampas, or indoor or smaller units are common permaculture elements. Aquaculture can produce more protein and produce per area of land than any other growing system.

Aquaculture systems can be implemented on all types of land: on swamps, wetlands, ponds or on land, on terraces and swales. It assists with drainage and water flow during the wet season and can be used as water storage for the dry season. This system can also be combined with other animals such as ducks, chickens, pigs to increase productivity of all systems.

Aquaculture in ponds

Aquaculture in a pond works great. Fish as well as the water, oxygen, sunlight, pond shape, plants, trees and other animals all play an important role in pond aquaculture systems. Here are some design considerations when installing your pond:

a. Oxygen – Oxygenated water is essential for a healthy pond. To add oxygen to water, you can add water plants or a submersible pump that agitates the water.
b. Location – The pond should be near a place with a continual supply of fresh water such as a water tap or rainwater collection tank or be the drainage spot for nearby earthworks.
c. Sunlight – Plant trees and plants around the pond edge to shade the pond. This reduces water evaporation and provides a cooler temperature for the fish. Also, adding banana trees to the pond provides partial shade and a place for algae to grow.

d. Size – It's better to make many smaller ponds rather than one large pond. To keep the water cool, the pond size should be a minimum of 3m x 3m, 5m x 5m - 10m x 10m is a good manageable size. Add a drainage pipe during the construction of the pond to direct overflow into another pond or swale system.
e. Depth – A variety of depths in a pond provides a cool place for fish to avoid hot sun and hide from predators. A shelf around the edge and deeper section in the middle is one way to shape your pond. Shallow depths should be 30-50cm deep and deep areas should be at least 1-2m deep.
f. Shape – A fishpond can be made any shape you like, but more edge is best. More edge = more veg = more fish food = more fish.
g. Liner – Clay is easier, cheaper and more eco-friendly, however you need a high clay content to hold water. Animals can also be used to help seal a pond such as pigs. Plastic liner is a good secondary option. Ferro-cement can also be used to reinforce the cement. See *earthworks* for more pond lining techniques.

Fish pond
www.diyaquaponicssystems.net/the-6-best-aquaponics-fish-species

Plants

On the pond

Plant areas near the pond edge hold the soil in place and prevent erosion. Pond edges are very fertile because they receive lots of water and nutrients (Many of the following species were found at: http://plants.ifas.ufl.edu/node/607)

- **Floating plants** – Water hyacinth, frog's bit, water fern, bog-mat, banana lily, spatterdock, duckweed, water lettuce, Indian water chestnut, cattail, water spinach, arrow root
- **Anchored plants** – Morning glory, watercress, water chestnut, willow
- **Emergent** – Lotus, taro, wild rice, rice, bulrush, reeds, water chestnut, water spinach, cabomba, anacharia, hornwort, arrowhead, blue flag, baby's tears, cattails, buttonbush, elderberry, golden canna, knotweeds

On the edge of the pond

- Grasses like vetiver, citronella, lemongrass, napier give structure to the soil
- Sweet potato, cassava, tomato, lettuce also grow well
- 1-2m from pond edge - Small fruit trees – Banana, citrus, papaya
- 2-3m from pond edge – Large fruit trees – Mulberry, guava, as well as other legumes

Fish

Many types of fish can be grown using aquaculture. Stocking 3 -5 fish per 1m2 is good for most fishponds. There are three categories of fish:

Carnivore – eel and catfish (some catfish are omnivore)
Omnivore – tilapia, gourami, catfish and mujair
Herbivore – carp

Introduce fish to your pond in the following order: First add herbivore fish, about 3 months later add omnivore fish, about 3 months later, add carnivore fish.

Fish food recipes

a. Fish Food Recipe - Grow a grain, harvest it, process it, grind it and mix it with a high-pectin fruit (mango, banana, crabapple). Then put it through a meat grinder extruder to make a uniform shaped strand. Lay this on cookie sheets and dry in the sun until the outside is crunchy and inside is moist. Cut into small bits according to fish size.
b. Maggot Bucket Recipe – Drill 1/2cm holes in 5-30 gallon bucket. Then fill the gallon bucket with food and

meat scraps. Make sure the contents are plenty moist. Leave it for a few days. Flies will lay eggs, hatch and begin to grow larvae. Feed them to fish or chickens before they hatch.

c. Fish Emulsion Recipe – Using a fifty-five gallon bucket or smaller with a tight fighting lid add dead fish and cover them with water until the container is full. Stir occasionally. Cover and seal for 9 months. It will transform into a golden and sweet thick paste and is an amazing source of nutrients and nitrogen.

d. Additional fish food ideas
    1) Fish also like cooked roots such as cassava, taro, sweet potato
    2) Feed insects, mice, termites and frogs to carnivore fish
    3) Legume leaves and seeds contain lots of protein and minerals
    4) Fish also eat moringa seeds and leaves as well as peanuts

Integrating fish with other animal systems

Many types of animal houses can be built on top of a pond so their feces falls straight into the water for fish food. You can build the pen above the water but it's also good to place the house above the water inlet before entering the pond so that the amount of water entering the pond can be regulated. Here are some general estimations:

Combining fish with other animals

Pond size versus number of chickens:

- A pond of 25m2 (5x5) = 5 chickens, 1-3 pigs or goats
- A pond of 100m2 (10x10) = 5-10 chickens, 3-5 pigs or goats

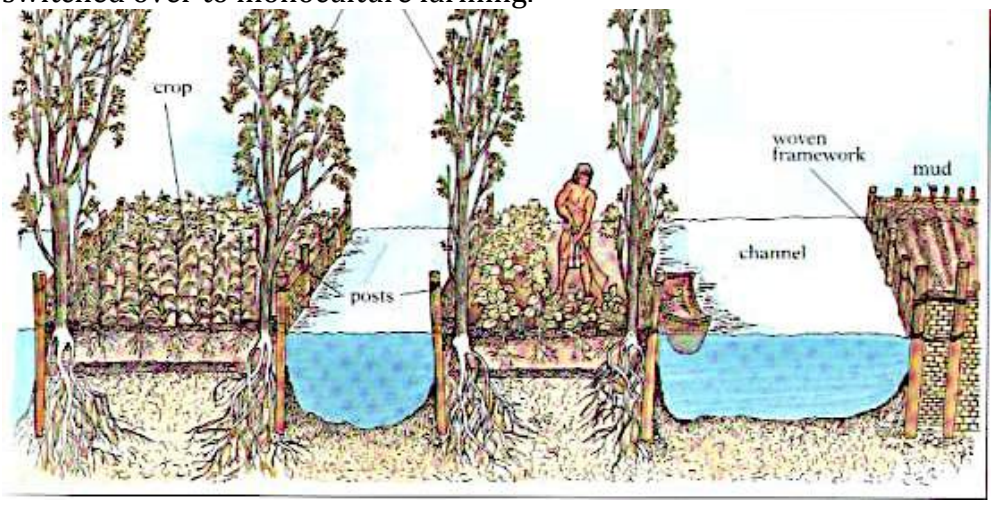
Chinampas

Chinampas are polyculture systems built on raised beds surrounded by canals or swamplands. Chinampas can produce yields 2-3 times greater than flat land farming. Chinampas regulate the microclimate by retaining moisture through capillary action. Annual and perennial crops as well as cover crops and fruit trees grow well on chinampas. Potential yields of chinampas systems:

- 8-14 ton per hectare of potato (versus 1-4 t/ha on flat land)

- 3.5-6.0 ton per hectare of corn (versus 2.6-4.0 t/ha on flat land)
- 1 hectare can support 15-20 people per hectare per year using chinampa farming

Chinampa systems have been practiced on saline lakes around Mexico, also Peru and Bolivia, for thousands of years. The Aztec people improved the practice by using chinampas for seed germination and seedling nurseries on the sides of the beds. Chinampas were managed by rituals linked to seasons in the solar calendar and to Aztec deities for water and fertility. Farming via chinampas has dramatically declined in recent years as people have switched over to monoculture farming.



Chinampas can produce 2-3 times greater yield than flat land farming

Sizing chinampa beds

Chinampa beds can be any size but are commonly 2-4 m wide and 20-40 m long. The raised beds are 0.5-0.7 m above water level, with sides reinforced by branches, willow trees or bamboo, with a thick layer of topsoil on the beds. Soil nutrients are provided from fertile organic wastes from the canal and reservoir bottom.

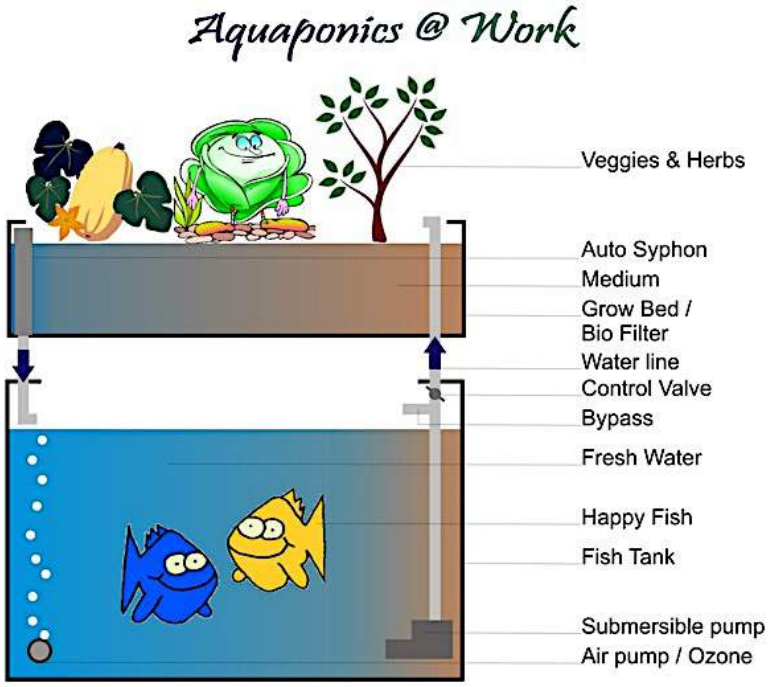
Aquaponics

Aquaponics is the cultivation of fish and plants together in a constructed, recirculating ecosystem using natural cycles to convert fish waste into plant nutrients. It harnesses the best attributes of aquaculture and hydroponics without the need for chemical fertilizers

or added nutrients. Aquaponics is like an urban version of aquaculture.

How do aquaponics work?

- Fish produce waste in the water
- Water is pumped into a trough filled with plants
- Plants filter water that returns to the fish



Aquaponics – How it works
www.4x4community.co.za/forum/showthread.php?t=196617

Food conversion ratio

This is a ratio of the amount of food animals must consume in relation to their physical growth. These statistics support the idea that fish are, by weight, one of the most efficient animals to raise:

Animal	lb food : lbs growth
Fish	1½:1
Poultry	2:1
Pigs	4:1
Cattle	7:1
Sheep	8:1

Lighting

For indoor growing, here are some guidelines for proper light intensity: A 1500w H.I.D. (high-intensity discharge) lamp will cover 8' x 8' area – 1000w covers 6' x 6', 600w covers 5' x 5', 400w covers 4' x 4', 300w covers 3' x 3', 100w covers 1' x 1'.

System design

- Basic flood and drain – Simplest design, appropriate for 1:1 grow bed to fish tank volume.
- CHOP (Constant Height, One Pump) – Enables 2:1 – 3:1 grow bed to fish tank ratio. More grow beds filtering the water is generally better for the health of the fish
- CHOP2 – Same as CHOP but uses barrels
- NFT – Look online for Nutrient Film Technique (NFT) or Raft technique

Aquaponics in totes
www.aquaponichowto.com/aquaponics-tote

Sizing your system

Recommended ratio of 1:1 – size of grow bed to fish tank – to start, move to 2:1 once you get it working.

Media and media depths

Use gravel without limestone or rinse gravel once you acquire it. To rinse limestone off gravel, fill sandbags with gravel and dunk them in a stream. To find out if gravel has limestone in it: Put gravel in a cup of

vinegar. If it fizzes, it has limestone. Lime will change the pH of the water. You can also buy expanded clay from a store.

Grow beds should be at least 30cm deep. This encourages bacteria to grow and supports enough density to support plants. Leave the top 5cm dry, the next 20cm for plant roots and the last 5cm for water collection. Fish tanks should be at least 45cm deep.

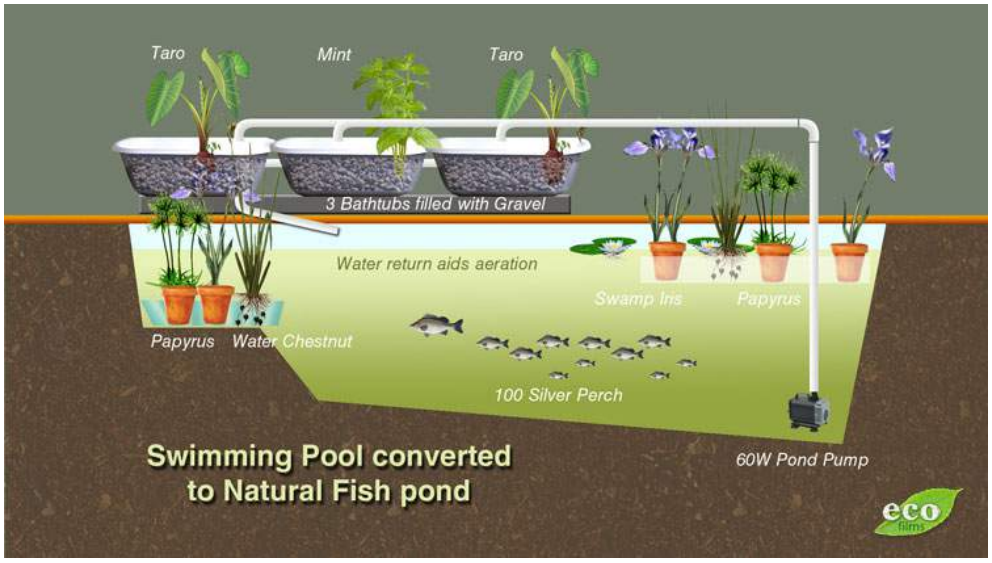
20L of water can hold 200 fish (at maturity weighs ½ kilo) and water $30cm^2$ of grow bed.

Aquaponics system, Annapolis, MD, USA

Fish tank

A round shaped tank is preferable to a square shaped tank. A short and wide shaped tank is better than deep and narrow. Avoid placing the tank in direct sunlight, cover or use shade to keep cool. Warmer water holds less oxygen.

55-gallon oil drum, IBC liquid totes, aquariums, bathtubs or pond liner to make good fish tanks. Go to www.gardenpool.org for other fish tank ideas.



www.ecofilms.com.au/converting-a-swimming-pool-to-grow-fish

Plumbing system

The pump flow rate (measured by liters per hour) should be four times the number of liters in your tank if you fill and drain grow bed 15 minutes every hour (recommended)

Use ½" PVC pipe throughout your aquaponics system. Do not glue the pipes in case you need to change them. You can also assemble an aeration pipe, spray bar or irrigation bar (look online for design) for simple irrigation techniques.

Vertical aquaponics gardening

When growing your aquaponics garden, consider these unique vertical gardening styles: window gardens, PVC towers, zip grow towers, stacking towers (look up online)

Stocking with fish – Choose fish that match the climate where you live. See *Pond aquaculture* for more information on fish.

Water – If using public water supply, fill up your tank, turn on your pump and run the water through your system for a day or two to remove the chlorine. Or filter it before adding fish.

Insects

Principle: Raise beneficial insects and keep pests away

Praying mantis

Insects are one of the most diverse groups of animals on the planet. There are between six and ten million living species of insects on earth. They represent about 90% of animal life forms on earth.

Insects provide several benefits to a permaculture farm. These include helping to pollinate plants, providing food for other creatures and eating parasitic aphids, mites and other unwanted pests. Types of beneficial insects include bees, ants, butterflies, beetles, dragonflies, termites, cockroaches, mayflies, cicadas, hoppers, wasps, flies and moths, among many others.

You can attract beneficial insects to your site by:

1) Planting "insect attractor/repellent" plants (like flowers)
2) Build an insect hotel
3) Build a bee hive.

Insect hotel

An insect hotel is a structure designed for insects to hibernate, lay eggs or find shelter and security from predators. The ideal location for an insect hotel is in full sun and protected from the weather. This ensures the heat required for the brood is present and wind or rain will not destroy their nest. Building on a wall or hedge facing the sun is a good position. Hotels should be relatively close to flowering herbs, wild flowers, garden, shrubs and trees.

Insect hotel
www.learninglandscapesdesign.com/insect-hotels

Insect hotel design notes

1. Bundle twigs together in an open-facing wooden box to attract **ladybugs**.
2. A bundle of bamboo or reeds, put in an old tin can and hung in a warm place will attract **solitary bees**. The bamboo must be cut to allow entry for the insects. Often people may add stems of elderberry, rose or blackberry shoots whose marrow can serve as a food source as well.
3. Large gaps between stacked bricks attract **isopods**, scavengers in the garden.
4. A sawn wooden log in which holes are drilled different sizes (2, 4, 6, or 8 mm), a few centimeters apart, drilled deep but not all the way through will attract **solitary bees, some wasps and bumblebees**.
5. Vertical slits allow **butterflies** to hibernate.
6. Sand the exterior of each piece of the hotel – The entrance must be smooth enough so that the delicate bodies of the insects are not damaged.
7. A terracotta flowerpot hung upside-down, filled with bundles of straw or wood wool is an ideal house for **earwigs**. Earwigs are good to have present in and near fruit trees as they eat plant lice that may settle on the tree and disturb fruit growth.

Bee Box)

Bees

Bees pollinate plants and produce honey, beeswax and propolis. You can build a bee box to attract bees to your site. There are many styles of bee boxes online if you google "bee box schematic".

Bee box

Bee boxes, or bee hives, are designed to encourage the health of the bee society as well as make it easy to remove the honey from the hive with the least disruption possible. Here is a good website for building a bee box: http://www.wikihow.com/Make-a-Honey-Bee-Box. *(Pictured left - Émile Warré*

Insect control

Here are a few ways to keep down the pests around your land:

Pond insect trap

- Cut a piece of tin into an "L" shape, build rain protection roof,
- Set vertically in a pond
- Hang a florescent light bulb in the "L"
- Place at the edge of a garden/pond area

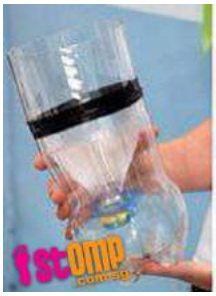
Fruit fly trap

- Wrap rotten fish in a fine mesh net to allow flies to enter but not exit
- Use liquid from rotten fish in a narrow-necked bottle to trap flies
- Place outside the vegetable garden to lure insects out of the crop

Simple mosquito trap

- Cut a 2-liter bottle in half
- Mix brown sugar with hot water. Let cool. When cold, pour in the bottom half of the bottle

- Add yeast, no need to mix. It creates carbon dioxide, which attracts mosquitoes
- Place the funnel part, upside down, into the other half of the bottle, taping them together if desired
- Wrap the bottle with something black, leaving the top uncovered and place it outside in an area away from your normal gathering area. (Mosquitoes are also drawn to the color black.)
- Change the solution every 2 weeks for continuous control

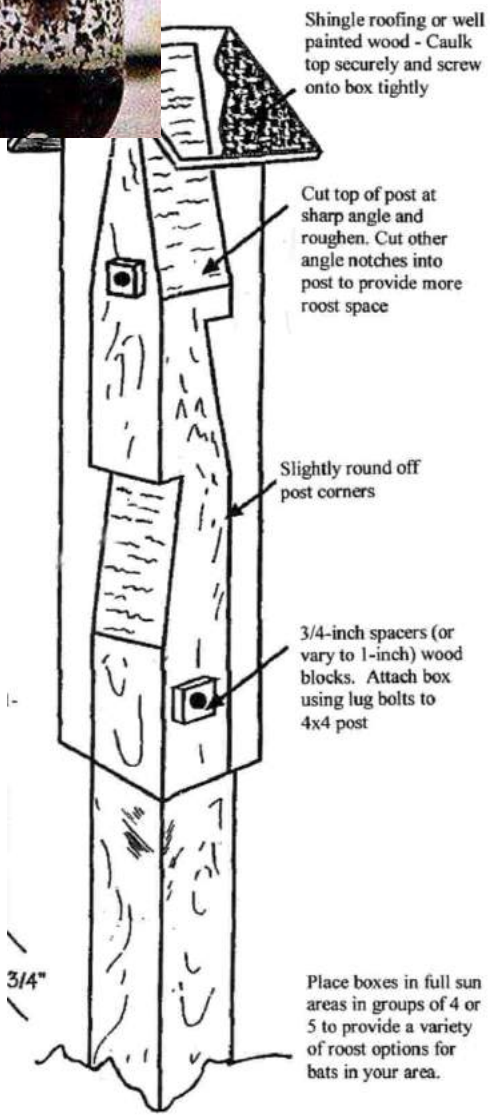


www.singaporeseen.stomp.com.sg/singaporeseen/this-urban-jungle/how-to-make-a-homemade-mosquito-trap

White oil

Pesticide to control aphids, mealy bug, citrus leaf miner, mites and caterpillars on fruit trees and flowers.

- Mix 2 cups vegetable oil and ½ cup liquid soap in a bottle
- Chop and blend 3 hot peppers + 3 garlic cloves (optional)
- Mix fermented brown rice juice with fermented green plant juice (optional)
- Shake until it turns white
- Dilute with water 10:1
- Pour into a spray bottle, let stand 24 hours



- Strain and spray on top and bottom leaves of infested plants

Bat Box

Bats eat insects. Installing a bat box is another way to rid your site of pesky mosquitoes (see image on the right)

Ant moat

Dig a small moat around each post or foundation of your house. Pour with concrete, leave a small trench 10-20 cm wide. Fill with water – ants cant swim.

Ant Moat
www.teakhousejava.com/?page_id=286

Frog pond

Frogs eat mosquitoes, moths and other flying insects. A frog pond (as opposed to fish, frogs like to eat fish eggs).

Animals

Principle: Raise healthy animals using the resources available

Duck pond, Okumura Farm, Samoeng, Thailand

Animals are an integral part of many mature farming communities. They can provide food, generate wealth, keep pests at bay, or provide love and companionship.

Permaculture farms can also raise animals for profit or food, but the principles behind animal husbandry differ from those used on commercial farms. The main difference is focusing on only raising animals that can be supported by the resources present on a permaculture site. If you need to purchase vast amounts of food to keep your animals fed, then you have too many.

Like all other aspects of permaculture communities, the goal is self-sufficiency. So before acquiring animals for your farm, you need to determine whether you have the necessary food, water and structures to keep them safe and healthy.

So whether you plan to raise chickens for eggs, raise goats for milk or raise cats for pest control, or if you just want to raise animals for their love and companionship, make sure you figure out the resources and space required to ensure their well-being, before bringing them home.

Animal food

Most animals eat a variety of food scraps, cereal grains, root crops and grass. If you plan on taking care of animals, make sure you have a

good source of food, whatever they require, before you take on the responsibility.

Animal shelters

Animal dwellings aren't much different than human dwellings – they provide shelter from the elements, and convenient places to sleep, eat and poo. It is good to design the type of living environments animals need to live and be comfortable before purchasing or acquiring animals. The following images provide some design ideas you could use to house various animals.

Chicken coop

Chicken coop

Rabbit hutch

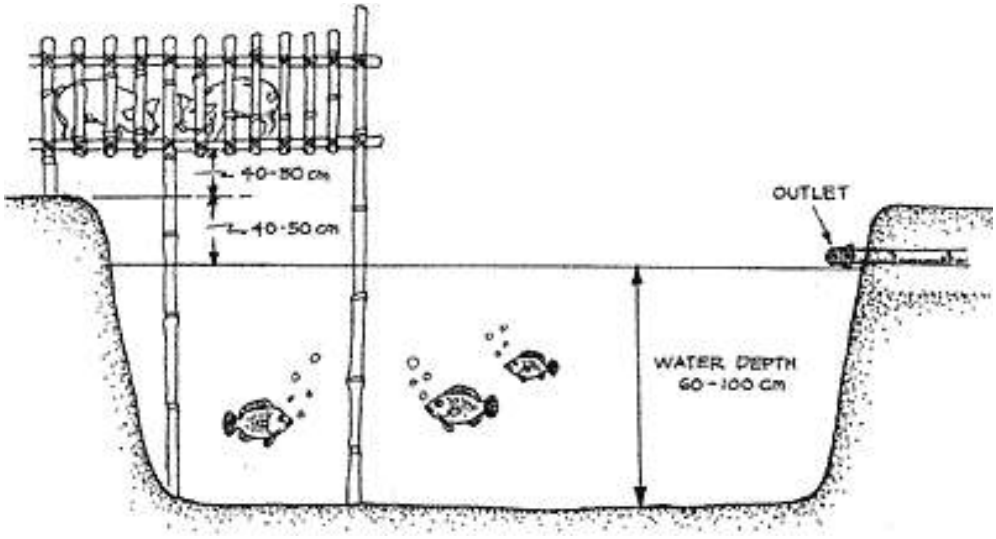
Rabbit hutch

Birdhouse

www.cwf-fcf.org/en/discover-wildlife/resources/faq/faqs/is-painting-a-bird-house.html

Raised animal dwellings

One animal dwelling design is to construct raised houses and allow the pee and poo to fall into a pond (to allow the fish to eat the poo, see aquaculture) or to make it easy to collect the poo.



Build animal pens above ponds to enrich the pond with nitrogen

Animal units

Animals eat about 2.5-3% of their body weight in food each day, no matter the livestock species. A 1000-pound cow or horse eats about

30 pounds of food per day. The 1000-pound example is a number called an "animal unit." A rule of thumb for productive pastures is 2 acres per animal unit. So two 500-pound cows or 200 5-pound chickens equals one animal unit and they would require 2 acres of space. You could also say each 100 pounds of animal weight is equivalent to 1/10 animal units. You can use this as a general rule when deciding on the number of animals to provide a home for on your farm. *Note:* Metric conversion: 1000lb = 454kg, 2 acres = 8094 m2 or 18kg/m2. *(http://www.hobbyfarms.com/livestock-and-pets/animal-acreage-ratio.aspx)*

Grazing

Grazing is a type of feeding, in which domestic livestock are used to convert grass and other forage into meat, milk and other products. It is important not to overgraze or overstock an area with too many animals. To prevent over-grazing, you can rotate animals to allow the vegetation to regrow.

Animal rotation (or Managed Intensive Rotational Grazing (MIRG))

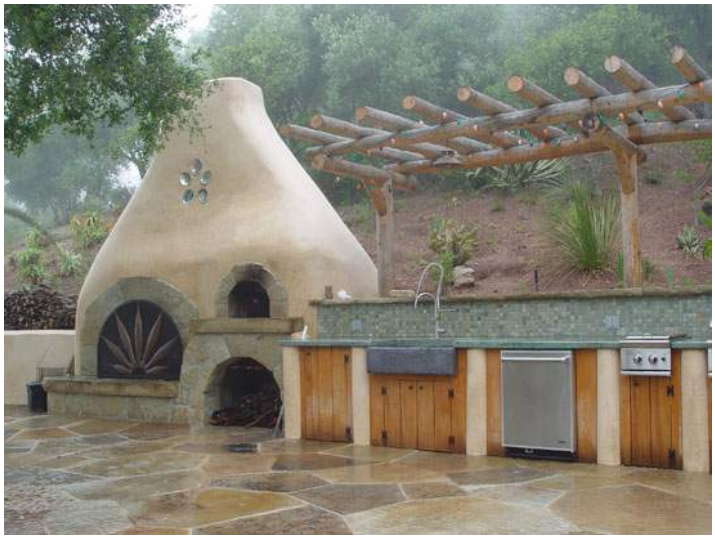
Managed intensive rotational grazing (MIRG), also known as animal rotation, describes a technique of rotating animals to freshly rested areas to allow the ground to recover. The length of time a paddock is grazed will depend on the size of the herd and the size of the paddock. It is important to let the pastures rest for about 14 days for each animal type after grazing. Resting grazed lands allows the vegetation to renew energy reserves, rebuild shoot systems, and deepen root systems.

Large grazers like cows, goats or sheep first skim off the highest, tough growth of plants, exposing tender shoots. Then smaller herbivores like pigs, chickens, ducks or turkeys come through and eat the tender shoots.

www.nrcs.usda.gov/wps/portal/nrcs/detail/nj/technical/landuse/pasture/?cid=nrcs141p2_018857

Kitchen

Principle: To prepare, ferment or preserve all food on site



A kitchen is a place used to prepare, ferment or preserve food. It is the end-stage of the garden: the place where plants and animals become food. In permaculture, kitchens are also one of the most visible reflections of the community's values: what it eats, how it cooks.

Kitchen elements

When designing a kitchen, it is important to allow enough space to prepare, cook serve and preserve food. One strategy is to design your refrigerator, stove top and sink within a few meters of each other.

The following elements conserve energy and enable you to prepare great home-cooked meals from your garden.

Cob oven

A cob oven is a fuel-efficient method of baking. Cob has high-insulating properties, which trap heat inside the oven, thus the heat recirculates.

www.mothergoosegarden.co.uk/2014/06/sat-july-5th-build-an-outdoor-cob-oven/

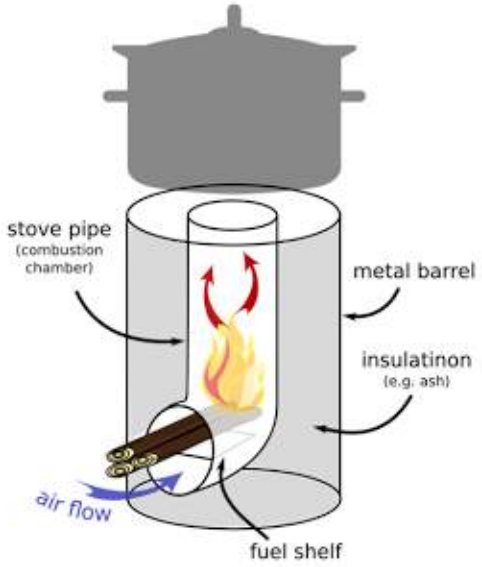
How to make a cob oven

1) Choose a location near your kitchen and build a base with earth, rocks or bricks until you reach the desired height
2) Arrange flat stone(s) to be the base of the oven. On top of the flat stone, mound wet sand in the shape you want the oven and cover the sand with wet newspaper
3) Lay an even layer of cob, about 5cm, on top of the sand
4) Cover to protect from rain and sun, it could crack if it dries too fast. Let it dry overnight. Once the cob has dried, now you dig out the sand from the door opening
5) Once you pull out all the sand, make a fire inside to burn off all the newspaper, and then make a fire and cook a pizza!
6) There are many design variations for cob ovens. Look online for one you like.

Fuel-efficient stoves

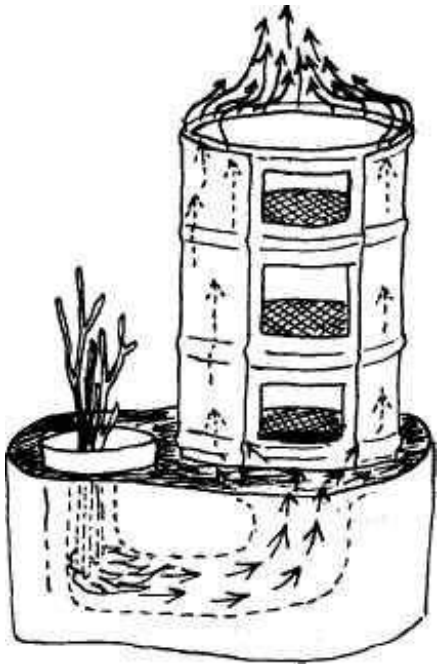
People cook food using many different methods. Natural gas works well, but can be expensive. Almost half of the world's population cook using wood. This method makes food taste great and keeps the kitchen dry and insect-free. However, wood is a limited or costly resource and the fumes from the smoke cause significant lung damage. The following types of fuel-efficient stoves illustrate methods to reduce the amount of wood needed for cooking.

Rocket stoves



Typical rocket stove design
www.stv-dshr.blogspot.in/2013/02/rocket-stoves-and-bio-char-at-florida.html

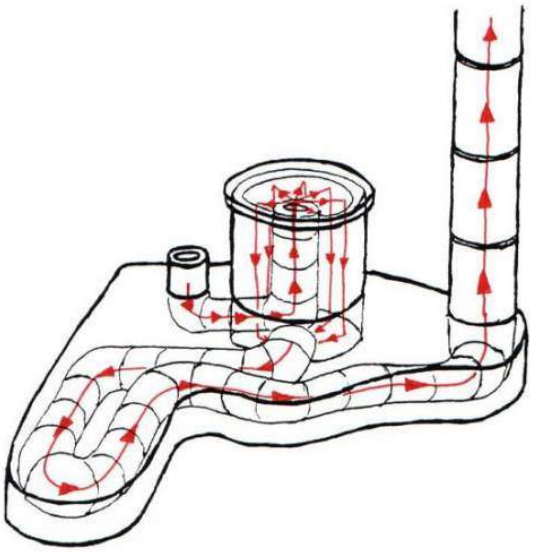
Rocket bread oven



Capturing Heat: Aprovecho, (www.aprovecho.net)

Multi-function rocket stove

The design below is a concept to create tunnels of cob and create either multi-burner stoves and or channel the heat into ducts to go throughout the house.



Solar oven

Solar ovens work great on sunny days. They do take a few hours, so be prepared to put your food in early in the day. It's nice to eat dinner at the end of the day by opening up a hot pot of fresh food cooked from the sun.

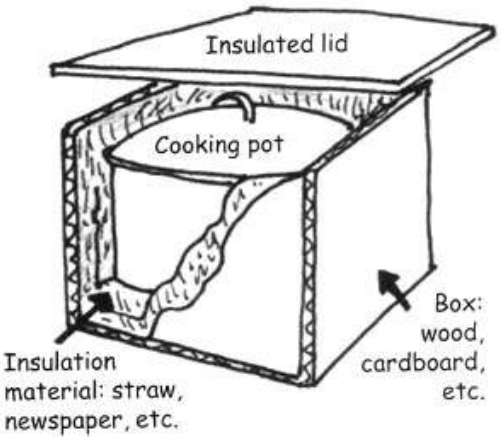
www.ecoenergy.org.ua/sdelay-sam/samodelnaya-solnechnaya-kuxnya.html

Dutch Oven

A Dutch oven is a cast iron pot and lid. You can make a big pot of something you want to cook/bake, place in a fire, put on the lid and cover it with coals. It is a good, fuel-efficient way to cook a nice slow cooked roast.

Hay box

A hay box is a highly insulated box used for keeping things hot for a long time. It can be as simple as a 200-liter metal drum, filled with sand, straw or even heavy blankets, leaving a space to put the pot and a thick insulated lid. To cook rice using a hay box, first, boil the rice and water on the stove. Let it boil for 2-3 minutes then remove it from the heat and put it in the hay box for 30-45 minutes. Once you finish cooking the rest of the meal, the rice is ready. You can steep teas if making wine or kombucha, or use it to keep food warm while you prepare the rest of the meal.



www.fao.org/3/a-a0218e/A0218E10.htm

Clay refrigerator

The *Zeer pot* refrigerator is a clay pot filled with wet sand, then capped with a smaller pot inside and topped with a good fitting clay top. This refrigerator has proven to extend the life of crops 10 times compared to traditional storage practices.

www.practicalaction.org/zeer-pots

Results of using a Zeer pot versus normal shelf life (test case in Sudan from Zeer pot website):

Produce	Shelf-life without a Zeer	Shelf-life using the Zeer
Tomatoes	2 days	20 days
Guavas	2 days	20 days
Okra	4 days	17 days
Carrots	4 days	20 days
Rocket	1 day	5 days

Plate-washing station

A 5-bowl washing system saves a tremendous amount of water. In the first bowl, you rinse off food residue. In the second bowl, wash your dish with soap and a sponge. In the last three bowls rinse off the soap. By the time your dish reaches the last bowl, it will be clean and you can hang it on the drying rack. Run the drain water into your greywater system (see *water* for a simple grease trap).

Plate washing area, Panya Project, Thailand

Cleaning note: You can clean just about anything with these three items:

1) *Lemon/lime*
2) *Vinegar*
3) *Baking soda*

Fermentation

Fermentation is the chemical breakdown of a substance. This process converts sugar to acids, gases and alcohol. The fermentation process occurs in yeast and bacteria, but also in oxygen-starved muscle cells, as in the case of lactic acid fermentation.

Carboy and airlock, two of the main materials you'll need for fermentation

Fermentation is where we turn basic vegetables into more complex foods. This chapter includes recipes for simple fermentation experiments you can do at home and become your own brew master.

Here are a few foods you can ferment. For full recipes and good descriptions of what you can ferment, (*Wild Fermentation by Sandor Katz)*:

1) Vegetables – Sauerkraut/kimchi, ginger beer, tempeh, miso
2) Fruits/honey – Wine, cider, vinegar, kombucha
3) Grains - Beer, sourdough, porridge
4) Milk – Yogurt, kefir, cheese, cream, buttermilk, butter
5) Household products– Soap, toothpaste, shampoo, conditioner

Here are some simple fermentation recipes:

Mead / T'ej / Ethiopian honey wine

Mix 3 cups of honey with 12 cups of water (always 4 :1 ratio, water : honey) in a *wide-mouth container.*
Cover with a towel or cloth
Set aside in warm room for 3-4 days
Stir mix at least twice a day (more the better)
Once it's bubbly, transfer into *small mouth container(s)*
Seal and apply airlock
Leave for 2-4 weeks, until bubbling slows

Ginger bug (for ginger beer)

Mix ½ cup of water
+ 2 teaspoons of ginger (skin and all)
+ 2 teaspoons of sugar
+ lime juice

Let it sit, every 2-3 days add 1 teaspoon of ginger and 1 teaspoon of sugar

Homemade wine

2 liters of water – dissolve 750g of sugar
If using fruit (you can use less sugar),
Boil for 30 minutes
Let cool, add yeast or leave open to absorb yeast from air
Leave out overnight, bubbles should appear
Sieve liquid into airlock containers,
Apply airlock
5-6 weeks bubbling will stop

Fruit scrap vinegar

1 liter of water + ¼ cup of sugar (60mL) + fruit scraps, finely-chopped (pineapple works great, as does any other fruit scrap)
Cover with cloth, store at room temperature
After 1 week, strain fruit scraps and discard
Ferment liquid 2-3 weeks

Sourdough

Mix 1 cup of water + 1 cup of flour in a bowl
Stir well.
Cover with a cheesecloth or towel.
Leave for 1 week, stirring at least twice a day
When it starts to bubble and smell sour, you can use it
Use half of the starter at a time to make a batch of sourdough
When you break the starter in half, feed the remaining starter the same amount of flour and water you removed

Tools and technology

Principle: Increase energy efficiency

Bio-char maker, Panya Project, Thailand

Permaculture communities strive for energy self-sufficiency – to generate power on their own and work to conserve it. This chapter brushes over a few basic tools, innovations and strategies useful for generating and conserving energy in a permaculture site.

Most communities around the world have access to basic hardware stores where simple hand tools and materials like pvc water pipes, cement, roof panels, etc can be found. Using the right basic tools for any job can get you where you want to go faster.

Hand tools

A hand tool is a tool which only requires human power. There are many types of hand tools used in permaculture. Examples of hand tools include: Hoe, shovel, pick-axe, machete, buckets (large and small), rake, handsaw, axe, secretors, box cutters/pocket knife, hammer/nails, wire cutters, pitchfork, garden fork, earth tamper, vice, measuring tape.

Common hand tools in India

Machine tools

Machine tools operate using electricity or a generator. Examples of machine tools used in permaculture are: Drill, circular saw, grinder, wood chipper, cement mixer, chainsaw, welding machine, generator, electric sander.

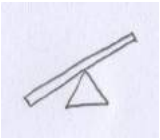
Wood chippers make great mulch in seconds

Heavy machinery

Heavy machinery includes large equipment that can do more work because of their larger size. They usually require gasoline or other consumable fuels. Renting or using heavy machinery can save time and labor. Examples of heavy machinery are excavators, bulldozers, cranes, graders, hydraulic tampers, grain grinders or other food-processing equipment.

Simple machines

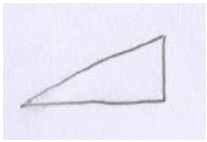
These are six simple machines used by people. Knowing about, understanding and using these simple machines could help lift or move heavy loads or other infrequent but important challenges. Here are brief descriptions of simple machines:



Lever

A lever is a simple machine that has a line that rests on a point. Place a load on one end and use force on the other. The force lifts the load. Example: Seesaw, scissors. Here's a video demonstrating a level machine lifting bricks: http://www.youtube.com/watch?v=8a9adBsGYDk (watch at 10:30).

Ramp



An inclined plane is a ramp. It has a slanted surface and helps you move things from lower to higher places. Moving something up a ramp takes less force. Example: handicap ramp.

Screw

A screw is an inclined plane wrapped around a column. Screws are used to attach things together, can be used to draw water from a well among many other innovations. A wood screw is an example.

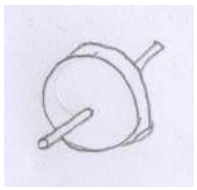
Wedge

A wedge is two inclined planes. It has a tapered end and a wide end. It is used to cut or split objects. Example: Axe.

Pulley

A pulley changes the direction of the force. A pulley consists of rope and a wheel. When you pull the rope, it lifts the load. Example: Flagpole

Wheel and axle



A wheel turns around a center rod that is called an axle. A wheel and axle is actually a lever that turns. Wheels make our work easy because they roll. Example: wheel.

Light – Solar Panels

Solar panels collect energy from the sun and convert it to useable electricity. In addition to solar panels, to harness solar energy you need a charge controller, inverter, and a place to store (i.e. batteries) or send the electricity (i.e. plug into the local grid).

Solar bottle lights

Solar bottle lights are plastic bottles filled with water and a little bleach to keep them clean and transparent. The bottles are fitted into holes on roofs of houses. The refraction of the light on the water during the day provides enough light to light a room. This innovation has been installed in over 1 million homes in developing countries where day lighting is unavailable. Here is a link for more information: http://www.bbc.co.uk/news/magazine-23536914.

Solar bottle light, Suncamp, Dominican Republic

Motion – Bicycle power

The motion of a bicycle can be utilized for elements requiring a rotational movement. Some useful variations include a water pump (see *Water*), sand sifter, laundry machine, mixer or to create electricity to charge phones and laptops. Google Bicycle power or "Dynapod" for more information online.

Heat – Bio-char maker

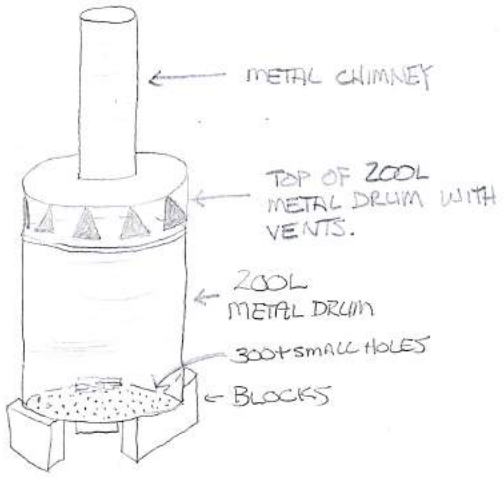
Bio-char is a type of charcoal produced using extremely high heat (around 900ºC), which provides many benefits to a permaculture site. Bio-char provides space for bacteria to latch on to as they enrich the soil, it ionizes water when used as a water filter and helps break down poop in a Humanure chamber. Also called activated charcoal, bio-char contains 9000 square feet of surface area in 1 gram or a piece the size of a pencil eraser. Add bio-char to your water filter, garden, compost

and your Humanure poo chambers. Watch this TED Talk by Rob Lemer for more information on bio-char: www.youtube.com/watch?v=NrDOLx57KUU.

Left: Topping the barrel with kindling after filling with bamboo
Right: The bio-char maker in action, reaching 900ºC
Bio-char maker at Panya Project, Thailand

How to make a bio-char maker

You will need 1 and ½ 200-liter metal drums, a steel pipe for a chimney. Any type of wood will make charcoal – the denser the better. As indicated in the video, make sure you seal the drum using mud after burning or else the charcoal will smolder into white ash. For step-by-step instructions on how to make a bio-char maker, watch this excellent video by Pun Pun Center for Self-Reliance in Thailand: *https://vimeo.com/75699743*.



Sketch of bio-char maker

Heat – Wood vinegar/charcoal maker

Wood vinegar is an insecticide useful for keeping pests away. It also eliminates odors from Humanure poo chambers as it smells like an oaky wood fire. Wood vinegar burns at a much lower temperature than bio-char and takes several hours to burn. The charcoal produced can be used for barbequing but doesn't have the same properties as activated charcoal because it was produced at a lower temperature.

Similar to the construction of a bio-char maker, all you need is a 200L metal drum and a few steel pipes. 200 liters of wood (a full drum, including air gaps) produces about 10L of vinegar. The denser the wood the better. However, bamboo will still work. Dilute with water about 100:1 (water: vinegar) to get more use out of each batch.

Wood vinegar maker, Kailash Akhara, Thailand

Economics

Principle: Create a surplus

Most current permaculture farms are not designed to maximize profit, like a conventional farm, but developing a sustainable business model is important to their long-term success. The payoffs from permaculture farming tend to be the pleasure one gets from growing and eating healthy food, deepening one's relationship with the environment and sharing with others the benefits of this lifestyle. But permaculture can also bring material gains. In this section we will talk about some ways that permaculture farms are succeeding financially – the strategies they have adopted to do so, the products they sell or trade to others outside of the community. There are countless ways to define and measure success in farming and in life. Doing permaculture helps highlight that.

Money comes from trees
www.islandbreath.org/2012Year/05/120523moneytree.jpg

Adding or creating value

Added value is when you make products from your site more valuable. When you grow peanuts and then make peanut butter, you added value to the peanuts. Adding value is about being creative. Here's a good article about Successful Permaculture Farms: www.permacultureapprentice.com/successful-permaculture-farms/. Some simple ways to add value to things at your site:

Potential goods and services

1. **Start a nursery** – You can't have enough seeds or plants. The more they grow the more valuable they become.
2. **Sell produce through a Community Supported Agriculture (CSA)** – Join a CSA to develop a good, repeat customer base.
3. **Grow plants** – Nurseries appreciate in value. Just grow plants. If you have more than you need and you don't sell them right away, they become more valuable.
4. **Restaurant/café/shop** – Sell products your community made.
5. Set up your site to **be a host site** for other courses – There are many people who have skills they could teach. If you provide them a place to teach, you can host courses and even learn something new yourself.
6. **Volunteers** – People will pay around $10 a day to work on your land. This can support people's food and maybe cover some materials.
7. **Events/festival** – Host local events or festivals.
8. **Hostel/guesthouse** – Providing guesthouse accommodations is a great way to create residual income with not much work once it's all set up.

Project Planning

Principle: Install your permaculture design

Use these questions as a guide to create a comprehensive permaculture design for any piece of land. Then go to www.permaville.com, register your site, upload a project and join the Permaville community.

General information

- What is the name of your project?
- Where is your project? Town, nearest city, country
- What are the GPS Coordinates of your site?
- What is the size of your site? (1 hectare=100x100m=10,000 m2=2.5 acres)
- Who is the owner of your land?
- What is the website of your project?
- Who is the contact person and email address of your project?
- What is the mission of your project?
- What are the goals of your land?
- What is the history of the land?
- How many people currently live at your site?
- Describe the existing conditions – Is there access, water, structures, etc?
- What permits do you need to get started?

Design methodology/strategies

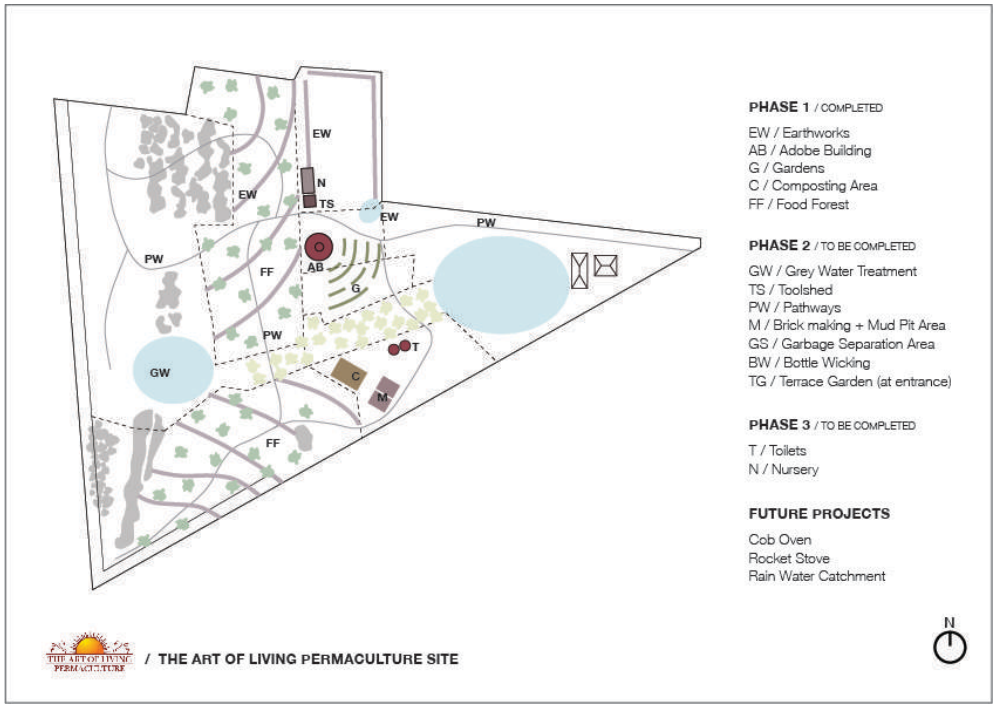
- What is the climate?
- Describe the seasons.
- What is the temperature range?
- What is the annual rainfall?

Satellite map / site map

Zoom in to your site on Google maps and print a PDF of the map. Or walk your site and sketch the boundaries. Draw a sketch on a separate sheet of paper. It doesn't have to be to scale. Include the following information:

- Site outline – Show the borders of your site

- Legend – Including the name of the project, location, climate, and size of land as well as symbols for existing infrastructure
- Infrastructure – Existing roads/paths, gardens, structures and water bodies.
- Compass and scale
- Zones and sectors
- Contour lines



Janine's permaculture plan
Art of Living Permaculture, India

Long-term plan

You can include all information on one site map or create multiple designs, as needed. Use the site map to illustrate a long-term plan for your site. List the most appropriate elements or details needed to reach each self-reliant goal.

1. Earthworks - Capture rainwater and provide access to the site
   - Which earthworks elements would be appropriate for your site?
   - *Indicate earthworks elements on site map*

2. Natural building – Provide housing for people and animals
    - What types of buildings do you need to construct?
    - What available materials do you have and would be most appropriate?
    - *Indicate natural buildings and structures on site map*

3. Water – Clean, conserve and reuse water
    - Where will you get water?
    - How will you filter water?
    - How will your transport water?
    - How will you dispose or recycle water?
    - *Indicate water bodies, elements and water lines on site map*

4. Sanitation – Produce no waste
    - What kind of toilets will you use?
    - How will you dispose of commercial waste?
    - *Indicate sanitation elements on site map*

5. Soil – Build healthy soil
    - What is the soil type? You can take multiple soil tests.
    - What are the available organic materials around your site (for soil building)?
    - *Indicate soil elements on site map*

6. Nursery – Save seeds
    - What fertilizers could you make?
    - Where will you source your seeds?
    - *Indicate nursery elements on site map*

7. Garden – Grow edible plants
    - What pioneer/nitrogen-fixing pants grow well at your site?
    - What kind of gardens will you design?
    - What kind of herbs and crops will you grow?
    - How will you water/irrigate the gardens?
    - *Indicate gardens on site map*

8. Trees – Grow useful trees and food forests
    - Where will you place your forest(s)?
    - What is the design of your forest?

- What kind of trees do you want to grow?
- What tree guild plants would work well?
- *Indicate the forests on site map*

9. Aquaculture – Raise healthy fish and plants
    - Where will you do aquaculture?
    - What kind of water body will you require for aquaponics?
    - What kind of fish will you raise, water plants, grow medium?
    - *Indicate ponds/aquaponics systems on site map*

10. Insects – Raise beneficial insects and keep pests away
    - What kind of insect elements will you install?
    - What kind of plants will you grow to attract beneficial insects?
    - How will you lure insects away?
    - *Indicate insect hotels, bee hives, bat boxes on site map*

11. Animals – Raise healthy animals
    - What kinds of animals will you care for?
    - What design considerations are important?
    - What will you feed them?
    - *Indicate animal houses*

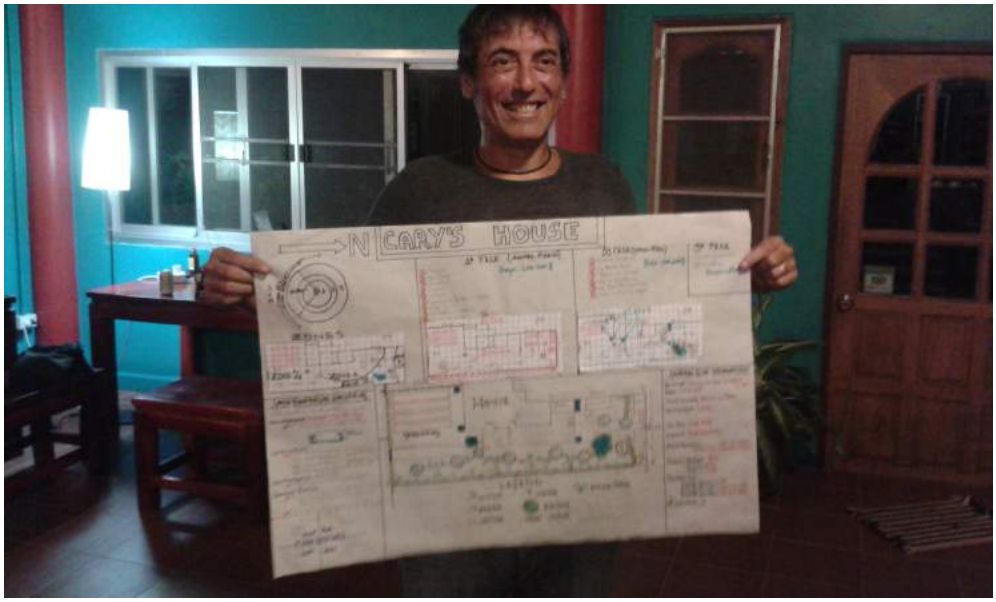
12. Kitchen – Prepare, ferment or preserve food grown on site
    - What sustainable kitchen elements will you include?
    - How will you add value to things you grow?
    - *Indicate kitchen and brewery on site map*

13. Tools and machines – Use energy efficiently
    - What hand tools, power tools, simple machines or heavy machinery will you utilize to install your permaculture plan? How could you make any tools or machinery?
    - *Indicate tool shed and workshop on the site map*

Phase plan

- What are the elements you will install in Phase I at your site? List them in order of priority.
- What are the details of these elements? Include general tasks, materials, and costs.

- Draw at least 1 **schematic design** for one of your elements. It could be a zoomed in area of your site (like zone 1 area) or it could be a technical drawing of an element or a flow diagram of all elements stacked together. Show as much detail as possible. Include any or all of the following details:
    - Materials, dimensions, details, procedure (if an element installation)
    - Flow diagram, model
    - Plan view/perspective
    - *Indicate on site map where it will be located*



Jose's permaculture plan for a house in Cuba
Kailash Akhara PDC, Thailand

Budget

- What are your general startup costs? (Land, tools, transport, fees, permits)
- What will your Phase plan cost to install (material costs)?
- Do you need to do any fundraising?
- What are your long-term material costs?
- What are your projected running costs? (Accommodation, food and overhead)

Implementation

- What is the estimated project start month/date?

- What is the estimated duration of this Phase? Consider a plan that will last 1-3 months.
- Who will install phase I – you and family/friends, volunteers, paid laborers?
- How can people participate?
- Will you hold any workshops or permaculture “blitzes” to install Phase I?
- What is the daily schedule for Phase I installation?
- Once you complete your phase I installation, what is the next step?

Permaculture Design Course Graduates, Kailash Akhara, Thailand

Conclusion

Green, natural, organic, sustainable, self-reliant, self-sufficient, off-the-grid, homesteading, permaculture – These words describe a deliberate way of living that goes with nature, not against it. Whatever you want to call it, nature works.

We've seen how permaculture strategies work in small, isolated instances. We need to demonstrate what this practice is capable of on a larger scale. We need to think and design and act and collaborate and communicate and spend time, money and resources to demonstrate what nature is capable of. Why? Because we can. How much more of a reason do we need? For God's sake, we're human. Let's see what we are capable of doing with this magnificent, perfectly functioning machine, slowly exploding before our eyes.

As the author of this book, I now sit in at the table of a small community I'm helping start called Magic House in South India. I plan to continue doing what I've been trained to do – to improve the land, to build structures, to grow vegetables and trees and then at some point create a surplus. It's not a matter of practicing permaculture because I have to, it's a matter of practicing it because I can.

Recommended Reading

Philosophy

These books offer great perspectives about how we live (*highly recommended):*

- Ishmael (Daniel Quinn)
- Story of B (Daniel Quinn)
- My Ishmael (Daniel Quinn)

Overview

- Introduction to Permaculture (Bill Mollison)
- Permaculture: A Designer's Manual (Bill Mollison)
- Permaculture Design: A step-by-step guide (Aranya)
- Holzer Permaculture (Sepp Holzer)
- One Straw Revolution (Masanobu Fukuoka)
- Gaia's Garden: A Guide to Home-Scale Permaculture (Toby Hemingway)
- A Pattern Language: Towns, Buildings, Construction (Christopher Alexander)

Earthworks

- Water for Every Farm (PA Yeomans)

Natural building

- Cob Builder's Handbook (Becky Bee)
- Cobber's Companion (Michael Smith)
- Earthbag Building (Hunter and Kiffmeyer)
- Practical Straw Bale Building (Murry Hollis)
- The Barefoot Architect (Johan van Lengen)
- The Hand-Sculpted House: A Practical and Philosophical Guide to Building a Cob Cottage: the Real Goods Solar Living Book (Ianto Evans)

Water

- Multi-barrier water system handbook/Bio-char handbook (Pun Pun/Aqueous Solutions)
- Living Water (Viktor Schauberger)
- Create an Oasis with Greywater (Art Ludwig)
- Rainwater Harvesting for Drylands (Brad Lancaster)

Soil

- Humanure Handbook (Joseph Jenkins)
- Natural Farming (Dr Arnat Tancho)

- Mycelium Running (Paul Stamets)
- Food of the Gods (Terrance McKenna)

Nursery

- Growing Under Glass (Greenhouse book)
- Seed to Seed: Seed saving and growing techniques for vegetable gardeners (Susanne Ashworth)

Garden

- All New Square Foot Gardening (Mel Bartholomews)
- The Backyard Homestead: Produce All the Food You Need on Just a Quarter Acre! (Carleen Madigan)
- You Can Farm: The Entrepreneur's Guide to Start and Succeed in a Farming Enterprise (Joel Salatin)

Trees and Forests

- Edible Forest Gardens, Volume 2: Ecological Design and Practice and Temperature Climate Permaculture (Dave Jacke)
- The Complete Illustrated Guide to Planning, Growing Storing and Preserving your own Garden Produce (John Seymour)
- Tom Brown's Field Guide to the Forgotten Wilderness (Tom Brown Jr)

Aquaculture

- Aquaponics Gardening (Sylvia Bernstein)

Kitchen

- Wild Fermentation (Sandor Katz)

Technology

- Dynapod manual
- Rocket mass heaters: superefficient woodstoves you can build (Ianto Evans)
- Capturing Heat (Aprovecho.net)

About the author

Brian Newhouse lived and worked with over a dozen community-based projects around the world for 10 years. He started teaching Permaculture Design Courses in 2014. When he's not doing something related to self-reliant living, Brian enjoys playing ultimate Frisbee and dancing to music. For more about Brian, go to www.bananadog.co.