CHAPTER 6

Soils: living organisms

All good gardeners and farmers have a passion for soils. They pick them up, run them through their fingers and smell them. And as you talk to these people you will find they tell you how they feed and care for their soils.

They will tell you what the soil was like when they first started gardening and, if you have time, they will take you to a place where the soil is thin and lifeless to actually show you how it once was. As you continue your relationship with the earth, you too will find yourself acquiring these same convictions. A friend of mine grows lyrical as she tells me about the stash of horse manure that she has discovered to feed her soil.

It is highly likely that neither you nor your children will see a healthy soil in your lifetime. Soils are not respected. They are compacted, eroded, dumped on, spat on, moved, covered, cleared, levelled, poisoned, flooded, drained, mined, turned upside down, and fertilised and sprayed with chemicals. Our ethical task is to improve those soils that will give high productivity and have been severely damaged, and to leave alone and respect those natural soils that support special ecosystems such as swamps, deserts, coasts and mountains. Some ecologists say that the greatest task on Earth is to restore soils to a healthy state and that we ignore this at our peril.

It is useful to think of soils as living organisms. Like forests, plants, water and climate, which are highly integrated living systems, they defy precise measurement and their functions are complex and synergistic. Soils are an unknown landscape that we barely understand.

Our ethical task is to:

- respect and leave untouched all naturally occurring soils that support unique ecosystems
- repair and protect all damaged soil
- respect soils as living organisms.

Our design aims for soils are to:

- carry out a whole site soil analysis
- recognise and repair damaged soils
- choose and use nutrients strategically.

If we don't have design plans for soils:

- the soil can become sterile
- acidity problems from poor fertiliser and water application techniques can result
- destructive farming techniques will continue to be practised
- lakes, rivers and ground water can be polluted and contaminated
- unhealthy food with too many nutrients or toxins in it will be produced
- soils will be exposed to wind and water erosion
- desertification and desiccation may result
- all soil life may be killed
- soil, crops and water will be lost.

Ecological functions of healthy soils

A healthy soil breathes, recycles waste, promotes active growth, stores nutrients and cleans water. Soils enable basic life processes for all living things. When soils are damaged, so is life as we know it.

Soil type and quality

Although very important, soil is not the primary selection factor for land because there are effective and proven techniques to repair and build soils quickly. However, if you are fortunate enough to have land with rich, sticky, red basalt soils then you are saved many years of hard work.

You will find that each part of your land, depending on its microclimate and use, has different soils. So respect that and work with it.

A simple analysis of your soil

Take three clear plastic or glass jars. Collect three different soil samples and put one in each jar—about 25–30 per cent of the jar's capacity. Now add water to about 80 per cent of the volume of the jars.

Shake each jar very well. Leave to settle for 24 hours then place the three jars in a row and look for the following:

- Loose, unbroken organic materials floating on the top. These indicate the soil has a nutrient bank to break down.
- Clear or murky water. Murky water has dissolved or suspended nutrients in it, which are immediately available to the plants; it's good.
- A fine silt layer on top of a denser one and then finally some coarse sand or gravel at the bottom. These tell you about your soil particle fractions. A reasonable layer of silt is also good because it, too, is a nutrient. A proportion of sand tells you your soil will drain well.
- Look at the colours of each sample. The closer to red or black the better.

Keep the samples and mark on them where they came from and the date. Over the course of one year, work on one of these soil sites, then repeat this test. Have you changed the soil?

Composition of a healthy soil

A healthy productive soil has a balance of:

- moisture
- gases
- mineral fractions
- micro-organisms
- organic matter.

Together these contribute to the main function of soil, which is to break down large physical and organic compounds to simpler ones that are absorbed by plant roots and used by soil organisms. Each of these five main elements not only differs depending on the soil but also interacts with all the other elements.

TABLE 6.1: FUNCTIONS OF HEALTHY SOILS

Function	How it works
Cleansing	Absorbs and filters some of the toxins in organic matter and transforms them to less toxic substances (for example, nitrites to nitrates).
Holding/support	Provides a medium to secure root systems of plants and support structures.
Respiratory	Absorbs atmospheric gases and recycles them from soil life via the metabolism of roots, organisms and the atmosphere. Think of soils as large digesters.
Digestive	Breaks down large physical and organic compounds (often wastes) to simpler ones, which can be absorbed by plant roots and used by other soil organisms as nutrients.
Storage/bank	Absorbs and holds water and nutrients for future use by plants.
Solvent	Dissolves natural chemicals for the roots to take up.

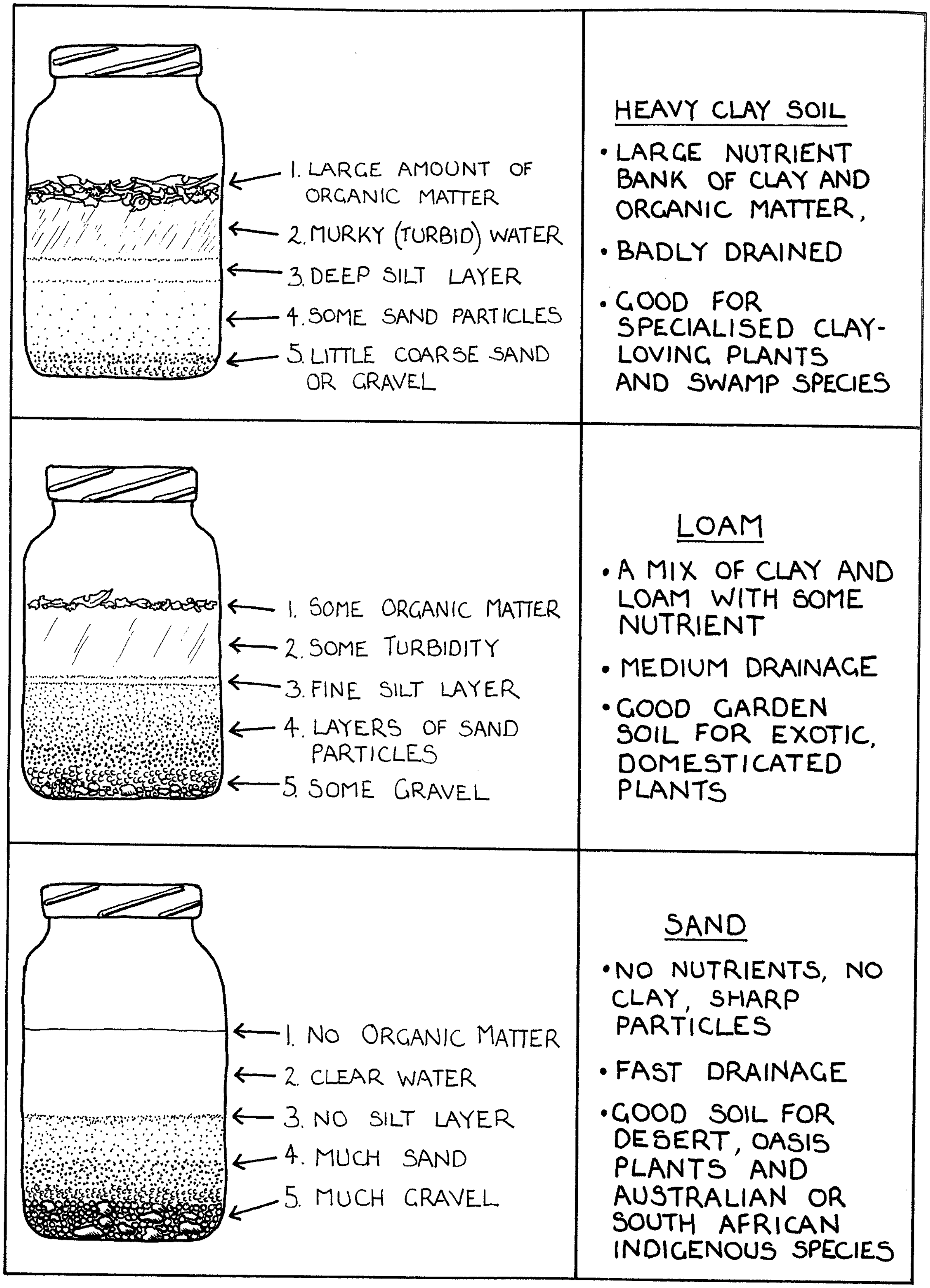

Figure 6.1 A simple soil analysis.

Moisture in soils

Water in soil is a weak acid or alkaline solution carrying the soluble nutrients that plants absorb through their root systems. And while these liquids must drain or the soil becomes waterlogged, they must not drain too fast or the soil dries out quickly. All plant nutrients exist in water-soluble forms.

The pH of soils refers to the acidity or alkalinity, which in soils is a measure of the solubility of various nutrients. So, if the soil has a pH of 8.0 then some nutrients are soluble and the soil is said to be alkaline. If the pH is 5.0 then other elements are soluble and the soil is said to be acidic. Adding lime to an acid soil to make it more alkaline, or sulphur to an alkaline soil to make it more acidic, changes soil pH. Most of the world's plants grow within a pH range of 5.5 to 8.0, and within this some plants will struggle and others thrive. Figure 6.2 shows you the acid–alkaline tolerances of different plants.

It is rarely desirable to apply a single chemical to change pH however, because we don't know how it interacts with all the other soil variables. The best solution for soil problems is always the addition of organic material.

Moisture moves from gas to liquid depending on air pressure and temperature. In soils, moisture as a gas moves upwards due to evaporation from wind or sun, or the pull of the water from the roots to the leaves due to transpiration. Water also moves laterally along bedrock. Gases and liquids move downwards after rain. Over-watering leads to leaching, which is the opposite of salination. Nutrient salts are washed down out of the root zone into the deep layers of the soil, even the aquifer. Some tree root systems penetrate deeply looking for this water.

In cloudy places where there are mists and fogs but no recorded rain, this moisture is absorbed by plant leaves and diffuses into the soil.

Scientists have recently declared that soil and vegetation moisture are extremely important in maintaining climate stability. Soils must not dry out due to poor farming methods and vegetation removal. In permaculture, keeping moisture in soils is important for plant growth. Refer to Chapter 4 on water for some techniques on how to do this.

Gases in soils

Gases in soils change pressure and type at different times of the day and in different seasons. They also move into and out of soils. How freely they move depends to some extent on the texture and structure of the soil. Gases in air are exchanged with those given off by plant roots and soil micro-organisms. If there is adequate oxygen then soil tends to be sweet-smelling. If there is little oxygen then other gases such as sulphur dioxide build up and soils smell rotten.

It has recently been found that ethylene gas is particularly important because when it is given off organic matter is broken down. (Ethylene gas is known as the 'ripening' gas and is given off when bananas, oranges and other fruit ripen.) In soils it cycles with oxygen, increasing the build-up of micro-organisms and other soil materials. Techniques that let more oxygen into the soil, such as forking or deep ripping without turning over the sod, are soil improvers because they assist the ethylene cycle.

Mineral fractions in soils

This refers to the type and size of rock and clay particles in soil. The 'feel' of a soil when you rub it between your finger and thumb defines its texture. When the particles are mainly sand and coarse gravel then soil feels rough and its texture is said to be gritty. When soil has minute particles, usually of clay minerals, then the soil has a smooth feel and is said to be silky (see Figure 6.3).

Gritty soils:

- drain quickly, and dry out quickly
- have few soil fungal diseases
- leach out soil nutrients (wash them into lower soil layers).

Silky soils:

- drain slowly and hold water for a longer time
- shrink when dry and swell when wet
- hold soil nutrients on the surface of clay particles
- when bare, form a claypan—a concrete-like surface.

If a soil is almost pure clay or pure sand it is called a 'difficult' soil. In both cases soil texture and

ACID AND ALKALINE TOLERANCE

QUITE ACID 4·0 – 6·0	SLIGHTLY ACID 6·0 – 7·0	NEUTRAL TO ALKALINE 7·0 – 7·5
BLACKBERRY	APPLE	ALFALFA
BLUEBERRY	APRICOT	ASPARAGUS
BRACKEN	BEANS	BEET
CHICORY	BUCKWHEAT	BROCCOLI
CHESTNUT	CHERRY	BRUSSELS SPROUTS
COFFEE	EGGPLANT	CABBAGE
CONIFER	GOOSEBERRY	CARROT
DANDELION	GRAINS	CAULIFLOWER
ENDIVE	GRAPE	CELERY
FENNEL	MUSTARD	CLOVER
FLAX	PARSLEY	CUCUMBER
LUPINE	PARSNIP	LEEKS
MARIGOLD	PEA	LETTUCE
MOSS	PEACH	ONION
OAK	PEAR	SILVERBEET
PECAN	PUMPKIN	SPINACH
POTATO	SOYBEAN	SWISS CHARD
PEANUT	SQUASH	ZUCCHINI
RADISH	STRAWBERRY	
RASPBERRY	TOMATO	
RHUBARB	TURNIP	
SHALLOT		
SWEET POTATO		
TEA		
WATERMELON		

Figure 6.2 Acid and alkaline intolerances of selected crops.

structure are improved by adding large quantities of organic matter.

Micro-organisms in soils

If there is good air–water balance and plenty of organic material, then soils will have trillions of micro-organisms. These are animals ranging from microscopic size to beetles, all eating, breathing, dividing, living, moving, clumping and dying. They aerate the soil, provide water channels, break down large molecules to smaller ones and, in themselves, are a part of the soil nutrient bank and will later provide organic matter for plants. The more organisms the better the soil health and pest management will be. The wider the range of organisms and the larger the population size then the faster the nutrients are cycled and the greater the range of nutrients available to the plants.

Organic matter in soils

It is not really possible to have too much organic matter in a food garden. Organic matter is anything that was once living, and comprises food scraps, grass clippings, hay, straw, leaves, sawdust, and even fur coats, dead cats, jute bags, old cotton curtains and your favourite old jeans. All become part of the soil nutrient bank. As these raw materials are broken down they become humus, a fine, sticky, sweet-smelling, nutrient-rich substance which slowly releases plant and animal micronutrients. Its nature is such that it helps sandy soils to hold water and nutrients and, conversely, helps compacted clay soil to become more open. Organic matter is the very best soil improver. It especially improves soil structure. When soils develop good aeration and balanced water-holding capacity they are said to have a good 'structure'. This looks like open airy bread.

All the soil components are interacting all the time. Soil particles are eroded and dissolved by water. Micro-organisms can't live without water or organic matter. A soil with no organic matter is near death.

Soil abuse

There are several ways in which soil can be abused, all with catastrophic results.

Removal of the surface vegetation

This is the most important cause of decline in soil structure and productivity. To obtain even greater yields and increase the amount of land under cultivation, more and more marginal land has been ploughed up and the vegetation removed. This practice has been disastrous for the soil which, after being dosed with chemicals, is then left exposed and unprotected from animal hoofs, wind, rain, cold and heat. Thousands of years of evolution of soil interaction with plants, animals, air and water is reversed by the removal of surface vegetation and the results are:

- salinity of dryland and irrigation soils
- wind and water soil-eroded land
- toxic soils from chemicals, biocides or nuclear contamination
- soil acidity from overuse of clovers and phosphates
- soil-structure decline from inappropriate farming methods and fertilisers.

Application of artificial fertilisers

If all the fertiliser applied to a crop were taken up by the crop and used for harvestable growth there would be few problems. But, invariably, a significant proportion is not used and is lost. A combination of crop, soil and climatic factors prevents uptake from being complete. For example, rice grown in the tropics uses only 30–40 per cent of fertiliser applied to it. The other 60–70 per cent leaches into ground water, where it is almost impossible to remove, or moves into rivers where it provides the nutrients for various algae, sometimes toxic, which in turn clog the surface and prevent oxygen and sunlight from penetrating. Insoluble phosphates in soils lead to soil acidity (see Figure 6.4).

In addition, excess fertiliser, as mineral salts,

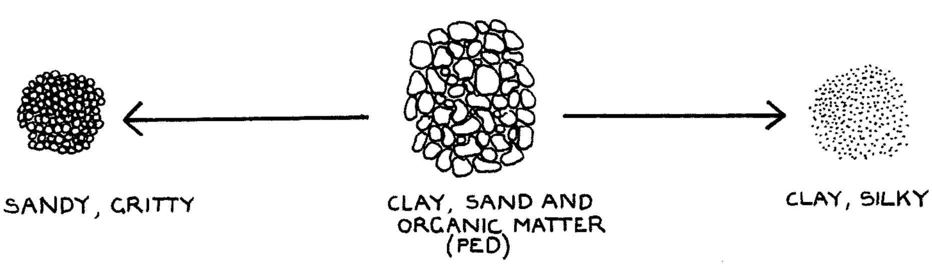

Figure 6.3 Soil texture and structure. Sandy soils are made up of large particles and have a rough gritty texture. Clay soils consist of fine particles and feel smooth and silky in texture. In both cases, organic matter will improve the structure and texture of the soil.

destroys the soil micro-organisms and the soil structure, which protects it against wind and water. And where there is loss of vegetation the soil erosion is accelerated. Food plants take up too much fertiliser and cause human sickness, or develop into weak plants susceptible to pest attacks.

Soils with excess fertiliser in them require a 'cleansing crop' which will absorb the surplus fertiliser before food crops are grown in them again. You can grow a cleansing crop of hay, for example, and then revert to food crops. When too much nitrogen fertiliser is used the plants are overly green and the animals and people eating them ingest too much nitrogen. In China where there are relatively high rates of nitrate, nitrite and amines in the diet, correlations are being made with oesophageal cancer (G.R. Conway and J.N. Pretty, *Unwelcome Harvest: Agriculture and Pollution*).

Accumulation of biocides

These are any chemicals used to kill living organisms, and include fungicides, weedicides, miticides and insecticides. They basically wage war against life.

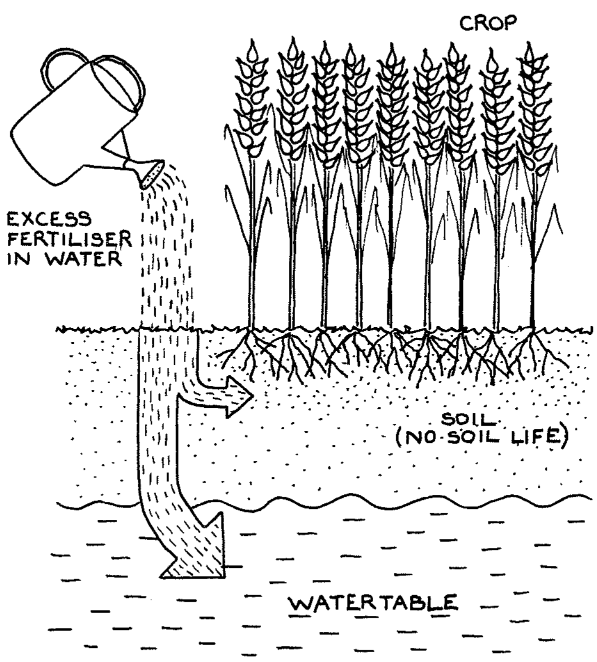

Figure 6.4 The effect of artificial fertilisers on soil. Excessive use of artificial fertilisers increases the acidity and alkalinity of soil and contaminates underlying water tables. This process is typical of monoculture crop systems which rely on large quantities of artificial fertilisers.

Many have a very long life in the soil, which means they continue to exist in the soil unchanged because they cannot move into one of the cycles of matter. Or they may move into plants and retain their potency. The shortest life for a biocide is a few hours, whereas others can last up to 40 years.

Bill Mollison recommends that people wishing to grow organic foods use clean farming methods and do not purchase land that has been used for growing bananas, sugar cane, deciduous fruit or orchard crops. A forest of long-term precious timber may work as a cleansing crop. However, by far the worst biocide is nuclear contamination, which persists for years in the soil, plants and water. The site of the 1950s nuclear tests in Australia will have to be locked up for more than 1000 years.

Vegetation clearing and water misuse

Soil salinity is a worldwide problem and occurs because the salts used by the plants for their mineral nutrition, which are normally distributed in correct proportions through the first 2 metres of soil, are concentrated into a narrower layer near the surface. Here the salts accumulate and become toxic. Figure 6.5 shows how the water table, which is normally kept at more than 2 metres from the surface, has risen and concentrated the salts in a much smaller zone as a result of the vegetation being cleared. The crop or pasture then dies. Farmers call it the White Death.

Inappropriate farming methods

Soil structure is destroyed when ploughshares invert the soil and then harrow it to break the clods into a fine tilth. This puts poorer-quality subsoil on top of good topsoil, and allows the fine, now structureless, soil to wash away, blow away and dry out. Today many farmers direct drill seeding into subsoil where last year's stubble remains to protect the topsoil.

In tropical and marginal dry areas, hoofed animals at stocking rates heavier than the earth can support compact the soil to a claypan that becomes impermeable to water. The air spaces in the soil are compressed and the soil becomes like concrete and won't absorb water. This state is called a caleche.

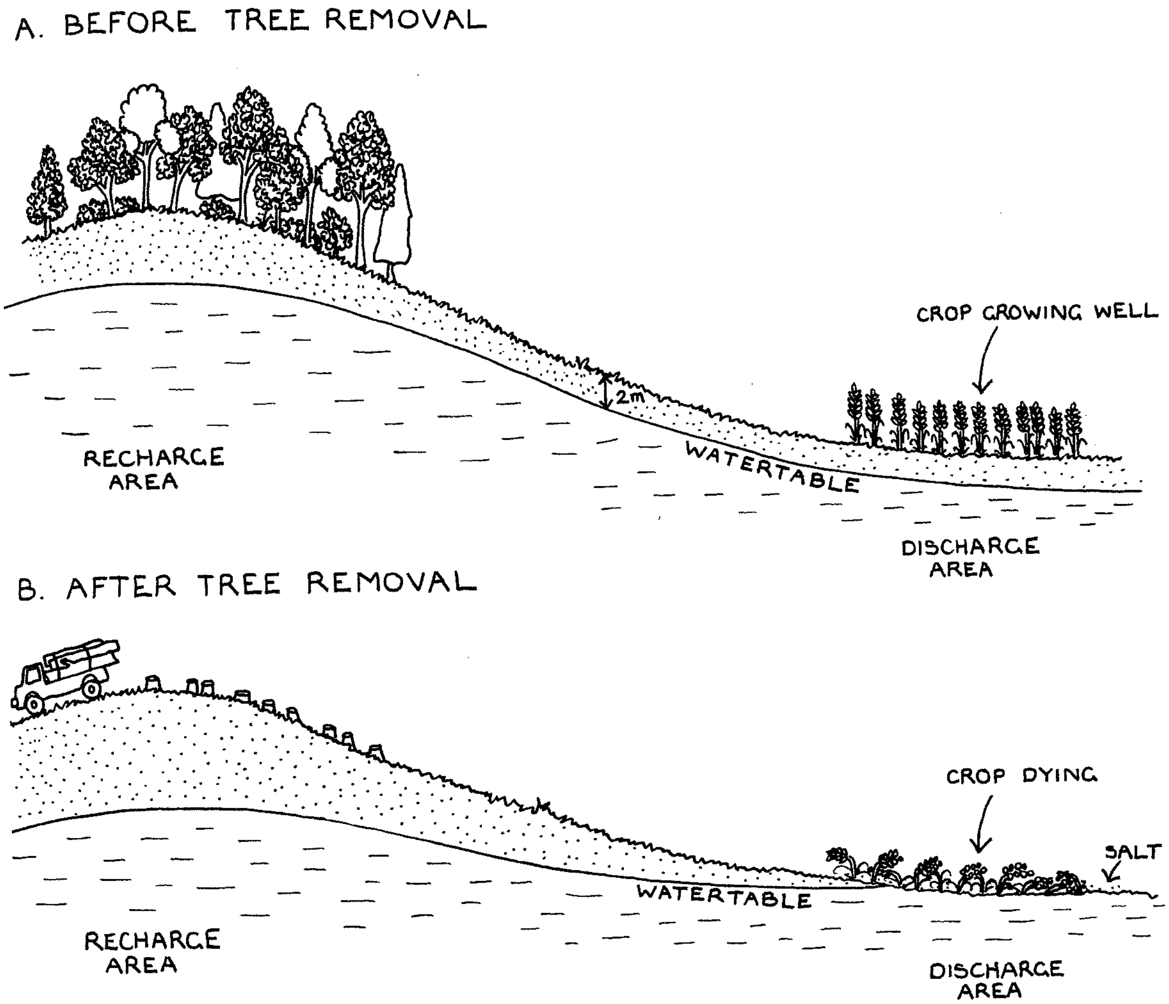

Figure 6.5 Tree removal and salinity.

Where heavy ploughing machinery has been used for many years, it always cultivates to the same level and leaves a claypan at the ploughshare depth. This claypan prevents water penetrating and so soils dry out as more water runs off and cannot percolate into the subsoil.

Strategies for repairing and rehabilitating soils

With the right techniques, patience and a lot of hard work, it is possible to rehabilitate abused soils.

Landshaping

Steep sloping land and sandy soils are best protected by terraces that follow the contours of the land. These should be constructed from plants such as vetiver grass, stone or timber risers. The terraces will hold the soil when there is heavy rain, wind or cultivation. Large and small swales function the same way.

Cover soils

Under natural conditions plants shed leaves, which then form a layer of mulch to protect the soil. Grasses and groundcovers grow over them, binding the soil with their adventitious roots as living mulches and protect them. Some shrubs grow branches to the ground and also protect soils. So in permaculture we become conscious of bare soils on farms and in gardens and the many ways to cover and protect them. A pasture should be so covered in grass you cannot see the soil between the clumps or runners. In your garden your spirit should be quiet when all your soils are well covered with appropriate mulches.

Keep water in soils

Soil holds and filters water, cleaning it and giving life to the soil. The first step in soil and land rehabilitation is to get water into the soil. You can use swales and a number of other techniques to slow water down and filter it.

Keep soils in place

Soils naturally move downhill to the bottom of slopes, where they are deeper and richer, leaving thin, dry soils on the tops of slopes. To prevent this, keep soils on the tops of hills covered and manage them so the water moves slowly off the heights and downhill. Also, soils in valleys and along riverbanks are prone to erosion and pollution from fast-moving waters and must be protected by dense plantings.

Altering soil qualities

Generally, alter soils as little as possible, especially chemically. Rather, grow in them what they support. If you have alkaline soils, then grow alkali-loving plants in them and in acid soils, acid-loving plants. Organic matter is the great panacea for all soil problems, whether you want to repair soil or increase its fertility, because it attracts a huge range of micro-organisms, which produce a huge range of nutrients.

Soils can be quite rapidly repaired. In permaculture, soil repair is fundamental to productivity and human health. Different methods are appropriate to different climates, sites and enterprises. You will learn about them when you look at each zone in Part Three. When you design a productive permaculture system, choose the appropriate techniques to repair the soil in gardens, orchards and farms.

How to feed your soil

You can easily achieve high yields without destroying soils or using artificial agricultural fertilisers or biocides. The secret is in supplying large quantities of organic matter. After the first establishment years of your garden or farm, you can become sustainable by growing all the necessary biomass for mulch or compost so you won't have to import or buy any fertiliser or mulch.

Your aim is to use all nutrients completely so there is no surplus, no waste and no pollution. You achieve this by growing a large range of plant species to use all the forms of nutrients, and by applying nutrients at times when they will be most fully utilised.

We will now look at all the ways to supply organic matter and nutrients for soils and plants.

Green manuring

This is when crops are planted specifically in order to be cut and returned to the soil as high-quality organic matter. The green manure crop is slashed two or three times while it is growing and before it flowers and seeds. It is then chopped and incorporated into the soil. This strategy quickly improves the soil texture and structure as well as providing nutrients. In winter you can use species such as rye grass, lupins or barley. In summer you can grow wheat, lucerne (alfalfa) or buckwheat. Use this strategy in orchards and on farms with depleted soils.

Legumes

These are plants that have the bacterium *Rhizobium* living in their roots. The bacteria supply the plant with nitrogen in soluble forms the plant can use, and they excrete surplus nitrogen into the soil around the root zone (the rhizosphere). In return, the bacteria receive energy from the plant. All legumes are 'nitrogen-fixing' if the correct bacterium is present in the soil. You know the bacteria are there if the roots have small white nodules on them and if, when you split the nodules, they are pink inside. The plant and the bacterium are together, symbiotically, nitrogen-fixing. Legumes are vegetables like peas, beans and broad beans, and trees and shrubs like acacias, cassia, leucaena and glyricidia. Many have a pea flower and they all have seedpods that split down both sides. All legumes are soil-improvers and supply nutrients. The leaves of legumes also have 25 per cent more nitrogen in them than other plants. They are usually pioneer plants and prepare the soil for the final species in a succession.

Use the vegetable legumes in a rotation in your food garden and leguminous trees in Zones II and IV.

Cover crops

These are very like green manure crops. They carry out the same function to protect the soil, and give products as well. They are often annuals. Cover crops are not cut because their function is to open up the soil, create a humidity interface, and protect it. Pumpkins and potatoes are good cover crops for hard compacted soils. The root systems of these plants open up the soil for air and water to enter while protecting it from erosion and desiccation. Cover crops are effective in large paddocks but are mostly used in gardens and orchards.

Organic mulches

These cover the soil and moderate summer and winter temperatures by insulating it from extreme heat and cold. They also protect it from erosion by retaining soil moisture, and in addition act as a weed barrier. When mulches are organic materials such as hay, grass clippings, straw, newspaper, old woollen underfelt and so on, they gradually add to the soil organic matter and function as a nutrient bank while they break down.

Living mulches are excellent in big areas and Zone II, while the dead mulches, which require more work, are appropriate for Zone I. They are too much work for the other zones unless you spot-mulch.

Animal manures

Animals are a vital part of the soil nutrient cycle. They carry out many functions, one of which is to supply nutrients in the form of manures. On the whole those animals that eat meat, such as chickens and pigs, have stronger manure (more nitrogen), which requires composting before it is applied to gardens. Cow and horse manure is weaker (less nitrogen) because they are grass-eaters, unless they have been stabled and have urine (nitrogen) mixed with it. You can place it directly around plants, but it often contains undigested weed seeds.

Poultry grazing in your orchard will, at the right stocking rates, keep it well fertilised. For the other zones (III and IV), use larger animals such as deer, sheep, cows and alpacas, but adjust the stocking rates and rotation so they are effective maintainers of pasture and browsers.

Composts

There are thousands of recipes for compost and every farmer or gardener believes totally in their own method for making it. So here is mine. I like it because it's little effort and it works. It was taught to me by women in Cambodia.

1. Make a 1-cubic-metre box or frame of wire (I have been successful with old iron). Have all your materials ready to fill it.
2. You need a big pile of cream materials like straw or dry grass, another pile of green materials like weeds and grasses, and some manure from chicken or pigs. Chop everything finely.
3. Now make layers. The rule is to use a ratio of 25:15:5. Start with 25 centimetres of finely chopped cream materials (this is high in carbon). Wet the layer with a watering can.
4. Add 15 centimetres of finely chopped green materials. Wet this layer with a watering can.
5. Add 5 centimetres of the manure. Wet it too.
6. Start again and continue until the container is full.

In warm climates you will have compost in 28 days. In cooler climates it takes a bit longer but is still very fast.

I don't turn the compost. When I want to use it, I take off the top few centimetres, which aren't composted, and make them the bottom layer of the next batch. Easy!

Nutrient broths

These are soups for crops. They get a very quick response and are particularly good for plants when you are not sure why they are ailing. There are a number of recipes. Most of them require buckets or barrels of water, or animal manure in a sack, or leaves such are comfrey that are dropped into the barrel and allowed to ferment. When the broth bubbles, the liquid is siphoned off and given to the plants to drink. Broths work by supplying liquids easily absorbed by plants.

Innoculants

Innoculants are a little like nutrient broths. Damaged soils are always low in micro-organisms, which break down large organic soil molecules into those able to be dissolved and absorbed by the plant roots. To make an innoculant, plant and animal matter is fermented to breed up a concentrated supply of micro-organisms. Ferments contain large amounts of fungi and yeasts, which are important in soil nutrition. This is then sprayed on fatigued soils, pasture or crop. The broth supplies the missing organisms and its use must be accompanied by inputs of organic matter, such as manures, mulches and composts, otherwise the organisms will die.

Biofertilisers

These are micro-organisms isolated from the roots of plants and which replenish nutrient salts such as potassium, phosphate and nitrogen in the soil. They are cultured in laboratories and grown on a humic acid substrate. They have enormous potential to transform farming currently dependent on chemical fertilisers. Biofertilisers:

- improve biodiversity in cultivated soils by increasing the populations of naturally occurring groups of soil micro-organisms
- replace 50–100 per cent of inorganic nitrogen (urea)
- increase yields
- improve plant health and reduce pests and diseases
- improve soil fertility.

Nitrate levels decrease in products grown with biofertilisers. High nitrate levels in vegetables are an indirect cause of a modern agricultural disease called methaemoglobinaemia. The causal link has been established. Other links are with bladder, oesophageal and gastric cancer.

Farmers who have become dependent on chemical fertilisers such as urea should at first partially substitute biofertiliser for urea, and then in subsequent years completely replace these chemicals. The arguments for using biofertilisers include:

- field trial results show that biofertiliser together with compost applications gives significantly increased yields—more than biofertiliser alone, and better than chemical NPK applications
- farmers can make biofertiliser themselves and so are self-reliant
- it is very much cheaper than urea
- it encourages good soil conservation and management practices
- it has regenerated exhausted soils
- it is environmentally benign because the organism does not move from the rhizosphere (root zone) while chemical nitrates are often pollutants moving into soil, underground and surface water.

Figure 6.6 summarises the best nutrients for different areas of farms and gardens. This is based on how much work is required, and how easy the materials are to obtain and use.

The future

Chemical fertilisers cost the Earth in fossil fuels and land degradation. All the techniques listed above are effective in restoring soils, and all of them can be implemented without high costs or large machinery. The future for soil rehabilitation lies with soil micro-organisms and large quantities of organic matter, which the micro-organisms require in order to build up their populations. In particular, biofertilisers have huge potential to increase crop yields, improve the texture, structure and water-holding capacity of soils, and provide better soil buffering of acidity and alkalinity than present fertilisers of any type. They also don't pollute soils or water.

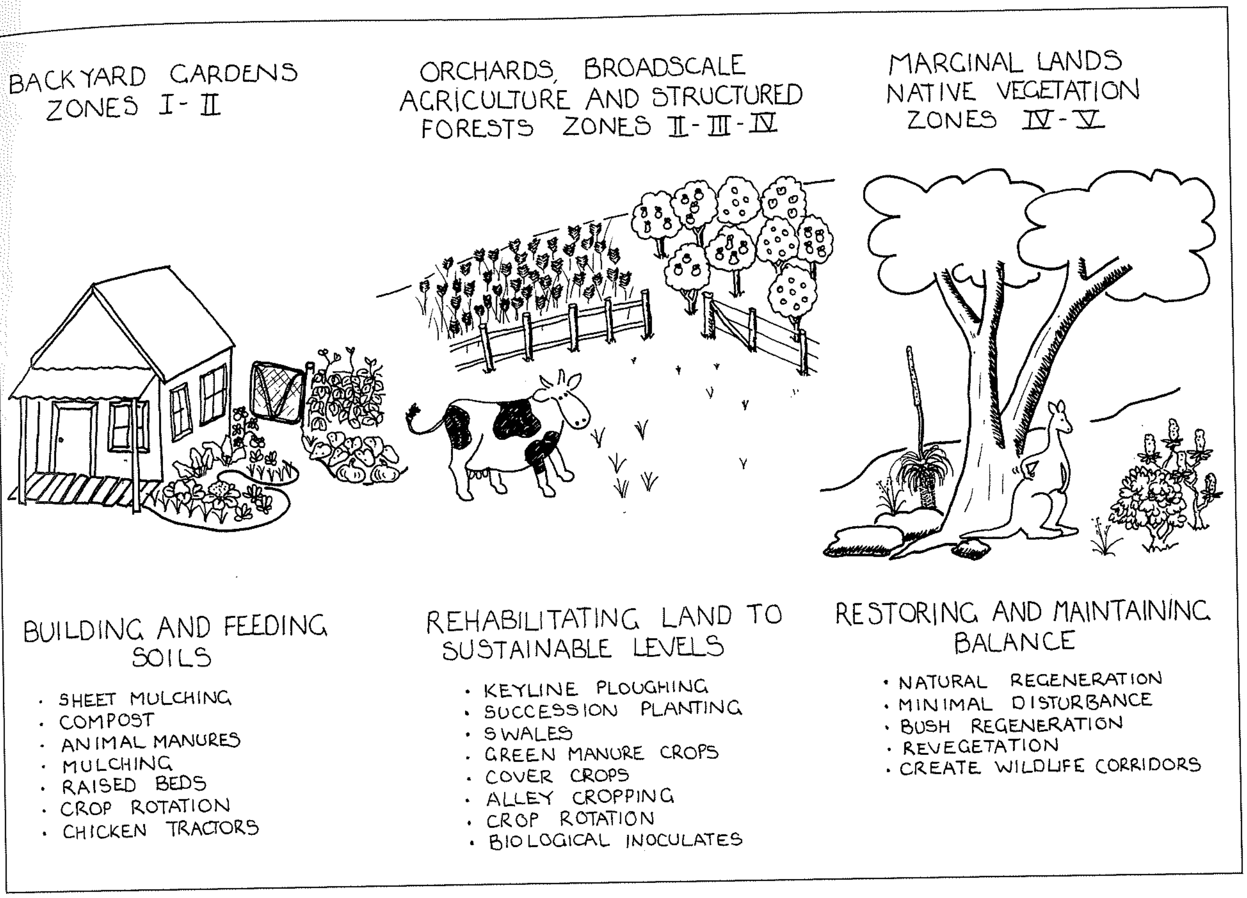

Figure 6.6 Techniques of good soil and land management.

Soil acidity is caused by insoluble phosphate in soils. However, some organisms, known as phosphate solubilising micro-organisms, can solubilise phosphates. By isolating special soil micro-organisms and bacteria, particularly those belonging to genera *Pseudomonas* and *Bacillus*, and fungi belonging to the genera *Penicillium* and *Aspergillus*, which possess the ability to bring insoluble phosphate in soil into soluble form by secreting organic acids, soil acidity can be reversed.

Traditional soil classification system

Before soil scientists were thought of, farmers knew their soils and what they would be capable of, and speedily recognised soil problems. They made field observations which, when put together, gave a comprehensive soil picture. This involved using all the senses to assess soil potential or soil problems and gave rise to the traditional classification system.

As you use the system, you will learn to recognise and remedy many soil problems without complicated analysis. Look at Figure 6.7 and see how many factors interact. When you put these together you will have made a very accurate picture of your soil because factors are interactive in soils and you will be able to consider them simultaneously. This is the best way of recognising soil types and how they work.

Try these:

1. List the plants in your garden and then look at the pH table in the text. Make an educated guess at the soil pH and then write it beside the plant name.
2. Dig up handfuls of soil from three different parts of your garden. On your site analysis plan, mark where they came from and plot the

TRADITIONAL CLASSIFICATIONS OF SOIL

CHARACTERISTIC	INDICATOR OF...
COLOUR	
• COLOURLESS/WHITE:	HIGH SILICA CONTENT
• LIGHT/WHITE:	LACK OF OXYGEN; LEACHED; HIGH CALCIUM CONTENT; ALKALINE pH
• YELLOW:	LACK OF OXYGEN; HIGH CLAY CONTENT; ALUMINIUM AND IRON
• RED:	IRON OXIDE
• RED/BROWN:	VOLCANIC, BASALT ORIGIN; IRON AND MAGNESIUM
• BLACK:	RICH IN ORGANIC MATTER AND NUTRIENTS; HOLDS MOISTURE
VEGETATION	
• EG. AZALEA, BERRIES, CONIFER, DANDELION, DOCK	ACID SOILS; USUALLY LEACHED; OFTEN COMPACTED, WITH POOR DRAINAGE
• EG. SALTBUSH, SPINIFEX, CLOVERS, VETCH	ALKALINE; SALINE; DRY SOILS
• EG. NETTLES	EXCESS NITROGEN; LOW HUMUS CONTENT; LOW MICRO-ORGANISM CONTENT
• EG. BLACK BERRIES	OPEN, DISTURBED SOILS
• EG. BRACKEN, BLADEY GRASS	SOILS RECOVERING FROM FIRE; GENERAL DECLINE IN SOIL FERTILITY
• EG. BUTTERCUP	LOW HUMUS; POOR DRAINAGE
• EG. THISTLES	LOW CALCIUM AND IRON CONTENT; HARD SOILS
PARENT MATERIAL	(AFFECTS STRUCTURE AND TEXTURE)
EG. SOILS DERIVED FROM	
• SANDSTONE:	SANDY; HIGH SILICA CONTENT
• SHALE:	CLAY; HIGH SILICA AND IRON CONTENT
• BASALT:	HIGH IRON AND MAGNESIUM CONTENT
SMELL	
• SOUR:	LACK OF OXYGEN; SULPHUR DIOXIDE (ROTTEN EGG GAS); ACIDIC
• SWEET AND EARTHY:	HIGH OXYGEN CONTENT; STICKY; CRUMBLY; PROLIFIC SOIL LIFE
• GARLIC:	ARSENIC IN SOIL
TASTE	
• SMOOTH AND SLIPPERY:	ACIDIC; SOIL WATER LATHERS EASILY
• WEAK SODA:	ALKALINE/MINERAL; SOIL WATER WONT LATHER EASILY

SOIL LIFE	
• WORMS:	GOOD MOISTURE CONTENT; RICH IN ORGANIC MATTER AND NUTRIENTS; LOW PESTICIDE CONTENT
• ANTS:	DRIER, SANDY SOILS WITH LOOSE TEXTURE
• SLUGS AND SNAILS:	DAMP AREAS; OPEN LOOSE MULCHES
• SKINKS AND LIZARDS:	DIVERSITY OF RESIDENT GARDEN INSECT LIFE
• WOMBATS:	DEEP, SOFT, MOIST SOILS
HOW SOIL HANDLES WATER	
• RUN-OFF:	BARE GROUND; COMPACTED SOILS; SLOPE TOO SEVERE
• WATER REPELLENT:	COMPACTED; ERODED; EXCESSIVE USE OF DOLOMITE
• SHRINKS AND SWELLS:	HIGH CLAY CONTENT; HOLDS WATER; NUTRIENTS OFTEN TIGHTLY BOUND; NOT GOOD FOR HOUSE FOUNDATIONS; CAN CRACK BUILDINGS; MAY BE USEFUL FOR MUDBRICKS
• FAST DRAINING: IE. A HOLE FILLED WITH WATER THAT DRAINS WITHIN TEN MINUTES IS CONSIDERED TOO FAST FOR GOOD PLANT GROWTH	EASILY ERODED; COLLAPSES EASILY; FEW FUNGAL DISEASES; MICRO-ORGANISMS AND NUTRIENTS MOVE QUICKLY UP AND DOWN SOIL PROFILE; NOT GOOD FOR DAMS
HISTORY	
• BARE GROUND:	POSSIBLE AGRICULTURAL OR INDUSTRIAL CHEMICAL CONTAMINATION
• GROWTH IN POOR SOILS:	POSSIBLE SITE OF OLD CHICKEN PENS, PIG YARDS OR HORSE STABLES
• NO TOPSOIL:	SITE COULD HAVE BEEN USED AS A QUARRY OR FOR FILL
• BAD CRACKS AND RUBBISH:	POSSIBLE SITE OF OLD TIP OR LANDFILL

different soils. Write down the texture of each one. Look at how the particles stick together then wet them and see if they roll into 'worms'. This is a test of soil structure.

3. How would you make one of your soils into a highly productive garden soil?
4. Bury a bucket of kitchen waste in your garden. After three weeks dig it up and see how many animal residents you can identify there.
5. Carry out a whole site soil analysis. Draw a 'mud' map and use coloured pencils to show the different soils in the different microclimates. Think about how you will repair them if they are damaged.