Principles of Natural Gardening & Farming

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Principles of Natural Gardening

Natural gardening is a method of gardening that mimics a natural **ecosystem**. It could be said that it is a 'do nothing' approach where the gardener allows a natural balance (**equilibrium**) to develop within their garden.

On a larger scale, this could be used as a method of agriculture. The natural method requires a fundamental shift in thinking from the standard method of horticulture/agriculture as the movement towards equilibrium can only occur if the gardener does not interfere with the **natural cycles**. Therefore, this method requires, and relies on, no turning of the soil, no pest or disease control, and no adding of dissolvable **nutrients**.

There are a few basic principles that need to be applied when setting up a natural garden/farming system. These include:

- Diversity
- Layering
- Succession
- Plant selection
- Habitat
- Mulch
- Water sinks.

If the above principles are applied, they will facilitate the development of the following, which are necessary for the success of the system:

- Biotic relationships
- Nutrient cycles
- Soil structure and water-holding capacity
- The water cycle and equilibrium.

All of these principles and developments will be discussed in more detail in the following pages.

Section One: Principles of a natural system

☯ Diversity

Plant a diversity of plants to attract the diversity of insects, birds, animals and microbes.

We hear a lot about **biodiversity** from ecologists and conservationists and about the importance of maintaining high species diversity. Have you ever wondered why the greater the variety of organisms the better it is for the environment?

The problem with 'Survival Of The Fittest'

It has been commonly understood that evolution is a process of survival of the fittest. Charles Darwin's observations fundamentally changed the way we view the environment. The problem is, his conclusion (or more to the point, the way he expressed it) has lead to a fundamental misunderstanding of how an ecosystem functions.

'Survival of the fittest' creates a mental image that all organisms are individual and in competition with each other with only the strongest surviving and evolving. This image of nature could not be further from the truth. If I was to explain the process of evolution as survival of the most co-operative we immediately create a different image of how the evolutionary process works. The organisms that survive are not the strongest individuals but the ones that have the greatest number of relationships with other organisms.

The higher the species diversity, the greater the number of relationships that can be facilitated within the system. The greater the number of relationships the more stable the system becomes.

For example, if a plant has an association with only one insect pollinator that feeds on the nectar from its flowers, and for any reason that insect becomes extinct, then it does not matter how strong and perfectly adapted to the environment that plant is, it too becomes extinct. If however, the plant has associations with many insect pollinators and one of those insects becomes extinct, the plant continues to survive through its network of relationships with the other insects.

Predator-prey relationships

A key association within nature is the predator-prey relationship. Although it is easy to see the advantage the **predator** gets out of the relationship it is not so easy to see the advantage for the **prey**. There are, however, some important advantages as follows:

- The predator will always go for the easiest kill, which means that they target sick or weak animals. This process develops populations of strong healthy animals over time.
- The predator will keep the populations of prey in check, preventing their numbers from out-growing the carrying capacity of the land. If this is not done then the prey will inevitably eat out their own food source.

If we look at this evolution on a very small time scale, lets say one season in the garden, then we are not looking at survival or extinctions of a species, but at population fluctuations. All gardeners dread the boom in population of pest insects or **pathogen microbes** that can cause significant damage or disease to their plants. Diversity within the garden can dramatically decrease these population fluctuations. The more complex the food web becomes the more stable these populations remain.

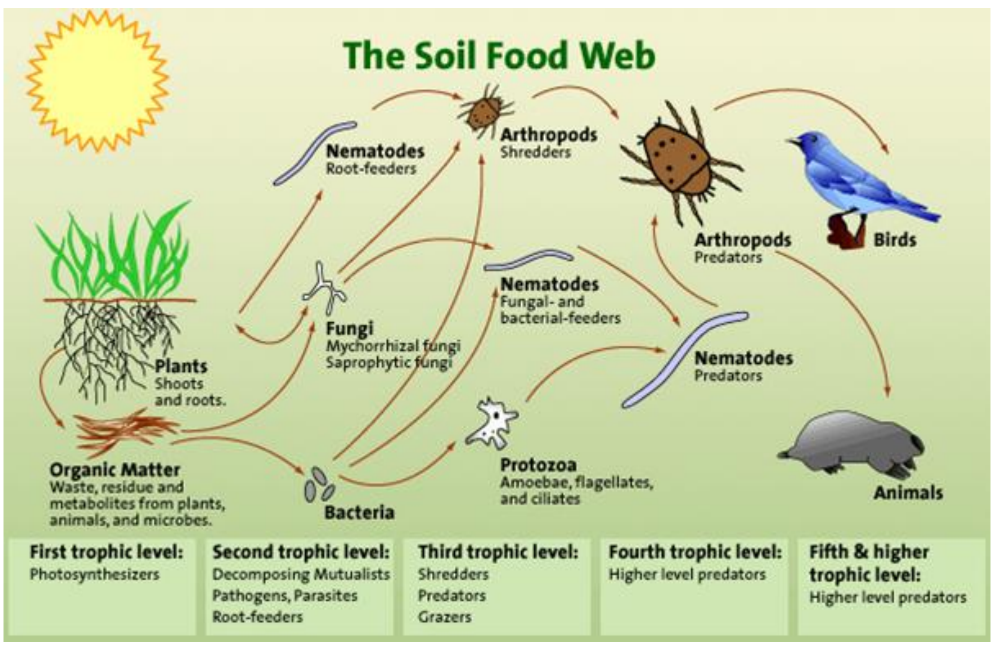


Fig. 1. The soil food web.

For example, if a caterpillar has only one predator in the garden and a dry start to the season prevents that predator insect from hatching, then there will be a sudden boom in population of the caterpillar. If however there are many different species of insect predators that feed on the caterpillar, and the dry season only prevents some from hatching, the caterpillar populations can still be kept in check because of the network of predator-prey relationships.

The higher the diversity the more stable the system becomes, and since plants are the beginning of the food chain and provide habitat, then the starting point is planting a diversity of plants to attract the diversity of insects, birds, animals and microbes.

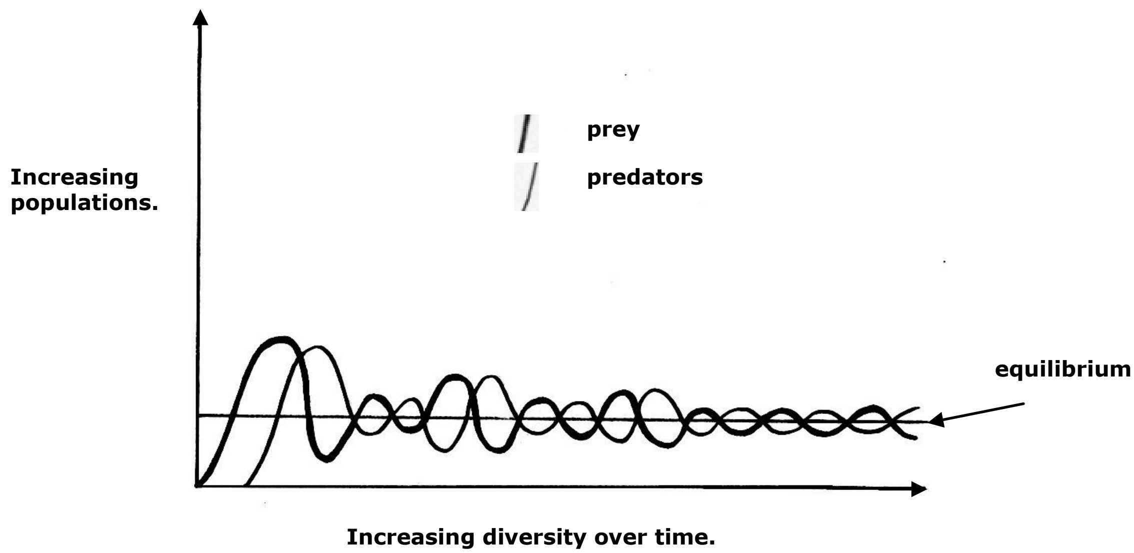


Fig. 2. Diagramatic interpretation of predator-prey population fluctuations in relation to levels of diversity over time.

☯ Layering

Include different forms of plants at varying heights to maintain moisture and provide habitat diversity.

Layering of plants is another key component of a natural system. If you look at a **rainforest**, which is the final **succession** of a plant community, with the highest level of diversity and disorder, you can see up to five layers.

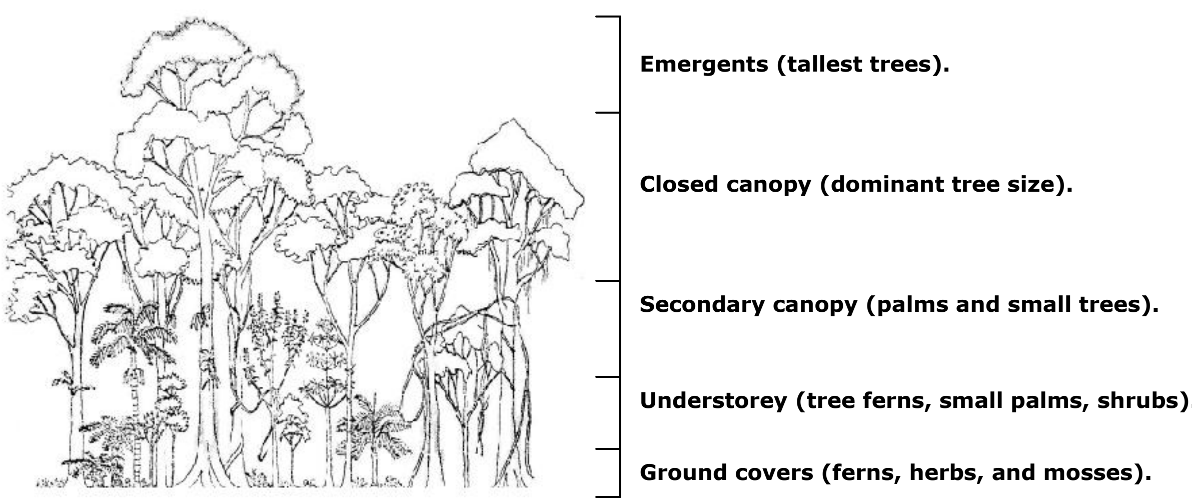


Fig 3. Layering in a rainforest.

As the layers develop in a forest ecosystem, the humidity released by plants through **transpiration** becomes trapped within that sheltered environment. Shading further maintains soil moisture levels by reducing the evaporative effect of the sun. As these two components develop there is an increase of moisture retained by the system through the micro water cycle of **evaporation** and **condensation**. Moisture is retained as dew in the evenings, returning lost moisture that occurred through evaporation and transpiration during the day.

Layering is important for maintaining moisture within the system, and also for habitat diversity. Having different forms of plants at different heights above the ground, e.g. trees, shrubs, herbs and ground covers, provide the diversity of habitats needed to attract a diversity of insects, birds and animals.

This layering above the ground repeats itself under the ground with root layering allowing a denser plant community to grow without all competing for the same space and resources within the soil below.

☯ Succession

Observe the succession process in natural systems and how water is the limiting factor to what types of plant communities will grow on a particular site.

Succession is the process of change within a natural plant community whereby layering and diversity increases over time. This is a key principle in the understanding of natural systems. Water is the limiting factor to the succession process.

When water availability is at a minimum, the plant community will not develop past the first succession. For example, a plant community is categorised as '**heath**' if lack of water is due to excessive evaporation, high runoff rates or simply lack of rainfall. On the other hand, a plant community is categorised as '**tundra**' if the lack of water is due to excessive cold conditions freezing soil water. Plants within the heath/tundra community are all adapted to full sun, low soil fertility and low water availability.

Wattle. Typical heath plant adapted for full sun and infertile dry soils. Has small leaves pointed upwards, light green to grey in colour, hard and waxy.

Grevillea. Another leaf adaptation for dry, infertile soils is the dissected leaf as shown on the grevillea pictured.

Fig. 4. Common leaf adaptations of heath plants.

At the other end of the succession process is rainforest. A plant community will only be able to reach this stage of highest diversity and layering if water availability is at its maximum. This may be due to high rainfall and/or low evaporation and low runoff rates. All plants within a rainforest community are adapted to shade, high soil fertility and high available moisture.

Lilly pilly. Typical rainforest plant adapted for shade and fertile moist soils. Has large leaves hanging down, dark green and glossy with prominent veins and a drip tip.

Palms and ferns. Another leaf adaptation for shady, fertile, moist soils is the large compound leaves as shown in the fronds of both palms and ferns.

Fig. 5. Common leaf adaptations of rainforest plants.

Sun intensity is another growth factor needed by plants. Rainforests, with the highest level of diversity and layering, will develop in tropical areas where sun intensity is at a maximum but rainfall still exceeds evaporation rates.

If moisture levels are below minimal water availability then a desert will result. A sandy desert is due to excessive evaporation and an ice desert is due to excessive freezing. If moisture levels are above maximum availability then a wetland system or swampy meadow will result.

Whenever a natural system is disturbed, the succession process will need to recur. For example, if we clear a rainforest, we change the two key components that facilitated the rainforest succession i.e. soil moisture and soil fertility. By opening up the canopy we have increased evaporation and decreased diversity and layering. The impacts of this will be seen as a decrease in soil moisture and soil fertility.

Any attempt to replant rainforest species in this disturbed area will prove to be unsuccessful. You would need to go back in the succession process and select plants that are appropriate for the current conditions. As the newly established plant community develops in both diversity and layering, it will facilitate the increase in soil moisture and fertility that will eventually enable the rainforest community to reestablish itself.

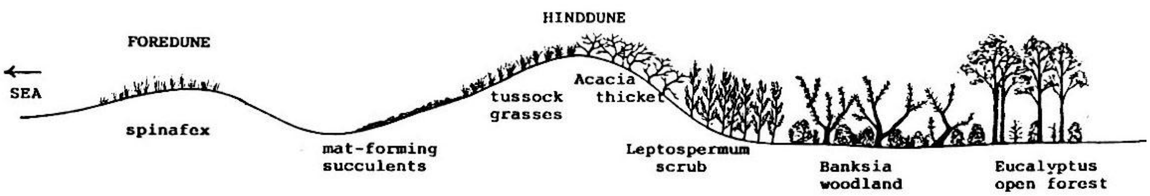


Fig. 6. An example of natural succession.

☯ Plant selection

Select the appropriate plants for the microclimate of the site.

Selecting the appropriate plants to facilitate the first three natural gardening principles i.e. diversity, layering, and succession, requires an understanding of the microclimate of the site. Also, if we are to develop a garden or farm that requires no adding of water or nutrients, then assessing the microclimate is vital.

Although the climate of a region may be categorised as temperate or tropical there will be many microclimates within that region that will influence the plant communities that naturally grow there. These microclimates will directly affect the amount of moisture that can be retained by the soil and in turn, effect the type of plant community that can grow there.

An example of this would be on the Central Coast where the climate zone is warm temperate, however the different plant communities that grow here are very diverse due to varying microclimates. In fact the Central Coast has everything from dry heath lands to rainforest communities.

The following factors influence a microclimate and, therefore, the plant types that need to be selected for a particular site:

- Aspect
- Slope
- Wind exposure
- Proximity to large water bodies
- Soil.

Aspect
The direction in which a slope faces can dramatically influence the amount of moisture retained within the soil. A southerly facing slope has low sun intensity and a low evaporation rate facilitating high moisture retention. The result is a suitable environment for a rainforest to develop. On the other extreme, the northern and western slopes have the highest sun intensity and evaporation rate facilitating low retention of moisture in the soil. The result is a suitable environment for the development of a dry schlerophyll forest or woodland.

Slope
The degree of slope will also impact the moisture content. A steep slope facilitates a high degree of runoff and a small amount of infiltration into the soil, while a gentle slope or flat ground facilitates a low rate of runoff and a high degree of infiltration into the soil. The result directly affects the plant communities that can grow on a particular site. The position on the slope will also have an influence on moisture with areas high on the slope being dryer than areas low down the slope. This naturally facilitates rain forest developing lower down on the eastern slopes and gullies, and wet schlerophyll forest higher up. The ridges are the driest areas of all and so develop heath plant communities.

Wind Exposure
Wind is another factor that needs to be considered before selecting plants. Wind has a drying effect on soil, increasing evaporation and transpiration. An area of high wind exposure will create dry conditions and an area of low wind exposure will facilitate wetter conditions. A southern or easterly facing slope on the coast that is buffeted by regular onshore winds will develop a salt tolerant heath community and not a rainforest community.

Proximity to large water bodies
Lakes, bays and oceans all create unique growing conditions for plants. The salt spray from oceans, and high humidity from evaporation from large water bodies and associated wetland areas, all require specific plant selection. Salt tolerant wetland communities develop around the lakes of the Central Coast and salt tolerant heath communities develop on headlands and dune systems adjacent to the ocean. Sheltered north and west facing slopes may develop littoral rainforests due to the high humidity reducing evaporation from the soil.

Soil
Soil is affected by all of the above factors. The condition of the soil directly corresponds to the microclimate and geographical conditions of a site, which need to be looked at closely when determining plant suitability. Soil fertility is determined by available moisture and organic content, not the ratio of sand, silt and clay particles. Another factor to take into account is the rate of deposition compared with the rate of erosion on a particular site. Soil accumulates lower down the slope creating rich, deep, moist soils, while on the ridges and high slopes, erosion is greater than deposition so soils become shallow, sandy, rocky, and dry.

☯ Habitat

Use small ponds and hollows (within logs, and piles of rocks and branches, etc.) in every garden bed to create habitat within the garden - increasing the level of diversity, and developing equilibrium.

Creating habitat within the garden is vital for attracting the diversity of birds, animals and insects needed to create the predator-prey relationship balance required to develop equilibrium within the garden. It is also the activities of these organisms that help develop the fertility of the system.

If you have carefully selected your plants, taking into account all the factors mentioned above, then you should be well on your way to creating appropriate habitat. However, the key component to habitat creation is providing a watering hole within the garden. Frog ponds and birdbaths are ideal but you can also place small ponds in every garden bed you create. Something as simple as an ice-cream container buried in the ground with a layer of pebbles and filled with water can achieve this in even small garden beds.

Another important component is to place things like hollow logs, branches, rocks, etc. in a pile, to create hollows in which small animals and insects can live in.

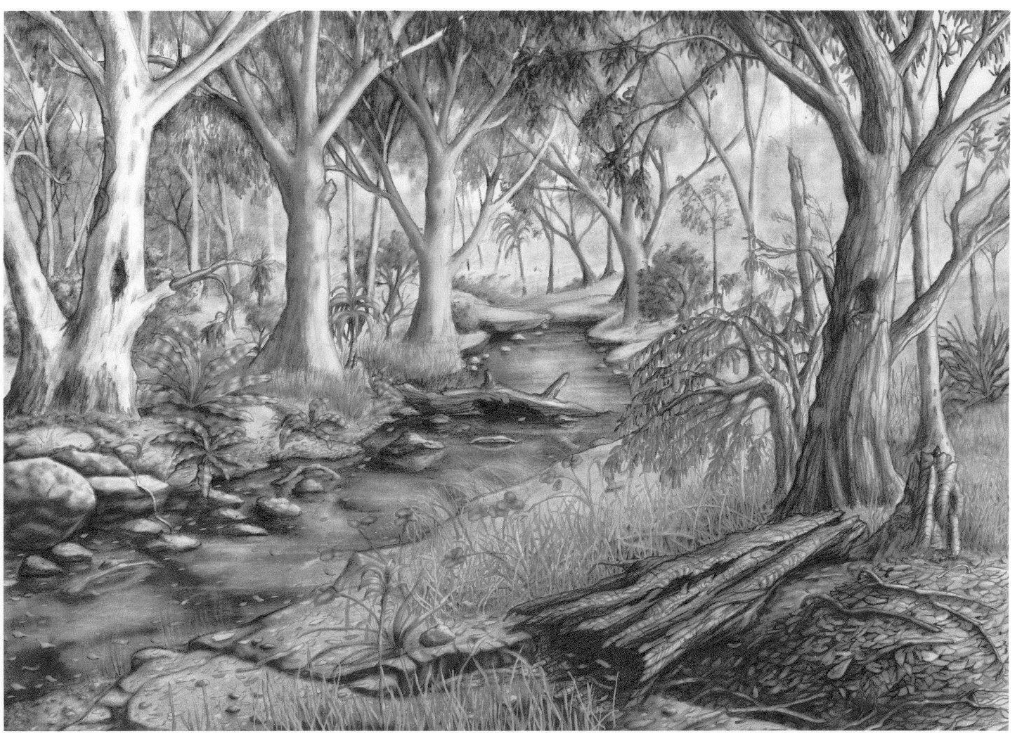


Fig. 7. Habitat in a natural environment. (Courtesy of Gosford City Council.)

☯ Mulch

Never leave the soil bare.

Mulch is vital to the success of the whole process. A fundamental rule of natural gardening is to never leave the soil bare. Mulch performs many roles that are vital for the development of equilibrium as follows:

- It shades the soil and reduces evaporation of soil moisture.
- It provides vital habitat for small insects and animals as well as providing conditions appropriate for worms.
- It insulates the soil creating a more moderate soil temperature throughout the seasons. **Note:** Plant growth is more affected by soil temperature than air temperature.
- It provides organic matter, which is broken down by microbes and insects, producing plant nutrients.
- During the breakdown of organic matter, microbes excrete organic compounds that join together to form humus particles. Humus is the key component in developing soil structure.
- It reduces weed growth by smothering undesirable plants.

A secret to successful mulching is to use coarse material that allows water to easily drain through. A combination of woody and leafy material is ideal.

Once the system develops, adding mulch will no longer be required. Leaf drop, and the shading effect of layers of vegetation including ground covers, will naturally perform this role.

☯ Water sinks

Try to replicate how a natural system would function by slowing the flow of runoff and using a series of ponds or water sinks with wetland plants to trap excess nutrients and increase soil moisture and fertility.

Setting up a landscape system that spreads runoff from rain through a series of contour channels or terraces running across sloping ground, and then capturing the excess water in a pond/wetland system lower down the slope, is a way to replicate how a natural system would function.

By slowing the flow of runoff and spreading it out across the landscape, we greatly increase the amount of water infiltrating into the soil higher up on sloping banks. By trapping it at the bottom of the slope in a series of ponds and wetlands, we are effectively storing water in the landscape. The practice of ponding river systems can fill the floodplain with fresh water, push salt from the landscape, and initiate the water cycle. These vital processes were managed by vegetation, prior to people clearing the land.

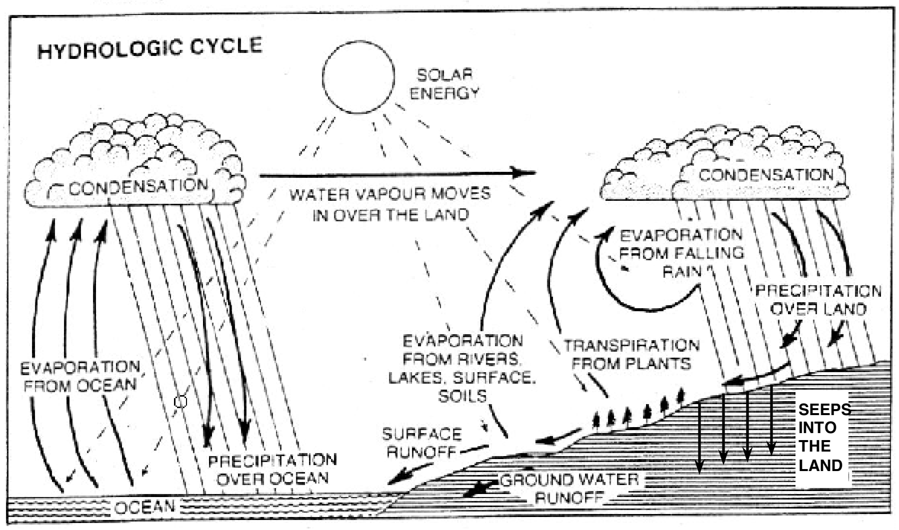


Fig. 8. The hydrological cycle.

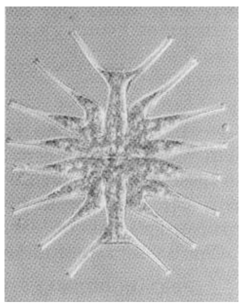
By using ponds or water sinks, we can increase soil moisture and fertility, allowing us to more quickly develop wet forest systems with higher diversity and layering. The key is to develop the system from the top of the hill or slope with first succession plants that will initiate the nutrient cycles and release fertility from the soil. As the soil moisture and fertility increases down the slope, the plant communities will become more diverse and more layered.

The wetland system traps excess nutrients that are taken up by wetland plants. These plants can be slashed at regular intervals and laid as mulch at the top of the slope. This process returns nutrients to the high ground and as the mulch breaks down, the nutrients rotate through the cycle again. Animals performed the role of returning nutrients to the high ground prior to human interference with the natural cycles.

Section Two: Developments within a natural system

☯ Biotic relationships and the nutrient cycle

Nutrients are tiny pieces of air, rock and water that are used by all living things to build body parts. Some of these elements are used to build an organic structure that is basically a container for carrying water (cells). Within the water, other elements perform vital chemical and biological reactions necessary for cells to function and grow. All living organisms are either a single cell or many cells joined together.



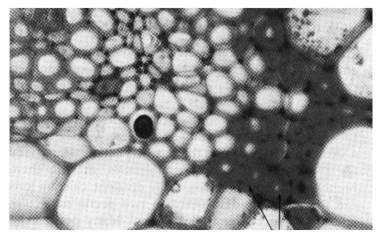


Fig. 9. Single-celled green algae (left); and multi-celled section of *Hakea* leaf (right).

Nutrients must be cycled through the entire environment from their inorganic form as rocks, air and water to their organic form as insects, animals, plants and microbes. They never remain permanently in the one form as they are constantly recycled through the environment.

Carbon, hydrogen and oxygen make up the bulk of organic matter and these form carbohydrate molecules. Sugar is a simple carbohydrate. Plants, algae and blue green algae make sugars through a process known as **photosynthesis**.

Carbohydrates make up the structural components of organic matter. In order to make different organic tissues, sugar molecules are connected together in varying ratios and combinations, creating everything from starch in potatoes to wood in the trunks of trees.

To alter the properties of the carbohydrate even further, a variety of other atoms from different elements can be attached. Nitrogen is one element that is used in the construction of **proteins**. When you add nitrogen and sulfur to the molecular structure of a carbohydrate, it results in the formation of a protein. Just as sugars (glucose) are the building blocks of carbohydrates, amino acids are the building blocks of proteins. Proteins form everything from muscle and hair to hormones in the blood.

Macromolecule	Subunit	Composition	Function	Example
Carbohydrates				
Storage polysaccharides	Glucose	Carbon, hydrogen and oxygen; except chitin has nitrogen	Storage of energy	
Starch				Potatoes Animal tissues
Glycogen				Bulbs of plants (dahlias, artichokes)
Insulin				
Structural polysaccharides			Cell wall components	
Cellulose	Glucose			Paper, cotton
Chitin	Modified glucose (*N*-acetyl-D-glucosamine)			Insect shell, crab shell
Pectin	Arabinose, galactose, galacturonic acid			
Hemicellulose	D-xylose			
Lipids				
Simple lipids		Carbon, hydrogen, oxygen; except phospholipids have phosphorus		
Fats	3 fatty acids and glycerol		Storage of energy	Butter
Waxes	Fatty acids and long chain alcohols		Protection	Coating on skins and fur of animals
Compound lipids				
Glycolipids	2 fatty acids, glycerol and carbohydrate (1–15 monosaccharide monomer)		Cell membranes	Higher plants, neural tissues of vertebrates
Phospholipids	2 fatty acids, glycerol and phosphate			Lecithin (phospho)
Steroids	4 carbon rings		Membranes and hormones	Cholesterol
Proteins				
Structural	Amino acids	Carbon, hydrogen, oxygen, nitrogen and sulfur	Support and structural material	Hair, silk, nails
Functional	Amino acids		Catalysis, transport defence hormones	Proteinases (enzymes) Transport of Cl^- ions Antibodies, snake venom Insulin
Nucleic acids				
DNA	Nucleotides	Carbon, hydrogen, oxygen, nitrogen and phosphorus	Storage and dictation of genetic information	Nucleus or chromosome
RNA			Transcription and translation of genetic material	Viruses

Fig. 10. Table of biologically important molecules (carbohydrates and proteins).

Nitrogen Cycle

The nitrogen cycle is one process that occurs within nutrient cycles. The nitrogen cycle is a process where **nitrogen gas (N_2)**, is absorbed from the air by micro-organisms and then converted into nitrogen nutrients, such as **ammonium (NO_4)** and **nitrate (NO_3)**. This is called **nitrogen fixation**. These nitrates dissolve in water and can be taken up through the roots of plants. Once the plants convert these nitrogen compounds into parts of their body (**assimilation**), they then become available to the entire biota of the system through either eating the living plant, eating other organisms that have eaten plants, or through decomposing the dead organic matter (**mineralisation**).

In order for the cycle to be complete, the nitrogen compounds must be converted back into nitrogen gas and returned to the atmosphere (**denitrophication**). Again, other microorganisms perform this function. In a balanced system, the amount of nitrogen being absorbed from the atmosphere through fixation is equivalent to the amount being returned through denitrophication (equilibrium).

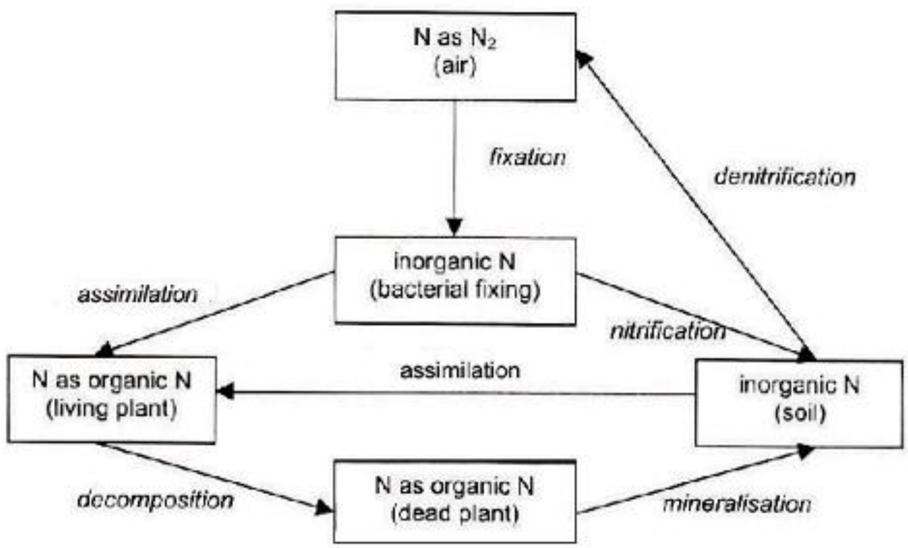


Fig. 11. The nitrogen cycle.

Although the entire cycle is a complex set of relationships, one specific relationship makes up a large component of the nitrogen fixing process: the **symbiotic** relationship between plants and bacteria that legumes engage in.

In this relationship, bacteria infect the root system of the legume plant and form nodules, within which they perform nitrogen fixation. As the cells of the plant and bacteria are in contact with each other, any excess nitrogen compounds that are not needed by the bacteria, move into the plant cells by the process of **osmosis**.

As this is a symbiotic relationship, the plants also benefit the bacteria. The one thing that plants can produce that bacteria cannot, is sugars. Through the process of photosynthesis, plants produce large quantities of sugar and any excess that the plant does not require moves from the plant cell into the bacteria cells via the same process of osmosis.

Legumes become active pools of nitrogen cycling, and through either being eaten or decomposed by other organisms, nitrogen is spread through the environment. Some of the excess nitrogen compounds and sugars exude from the root system, directly into the surrounding soil, providing a bounty for many other organisms living in or around the root zone. Legumes have the ability to quickly build the fertility of even badly degraded soils.

Phosphorus cycle

Phosphorus (P) is another element that is important for life. The nutrient that transports P into the plant is phosphate (PO3). P is a metal and is used to form a molecule that can transport energy around organic systems.

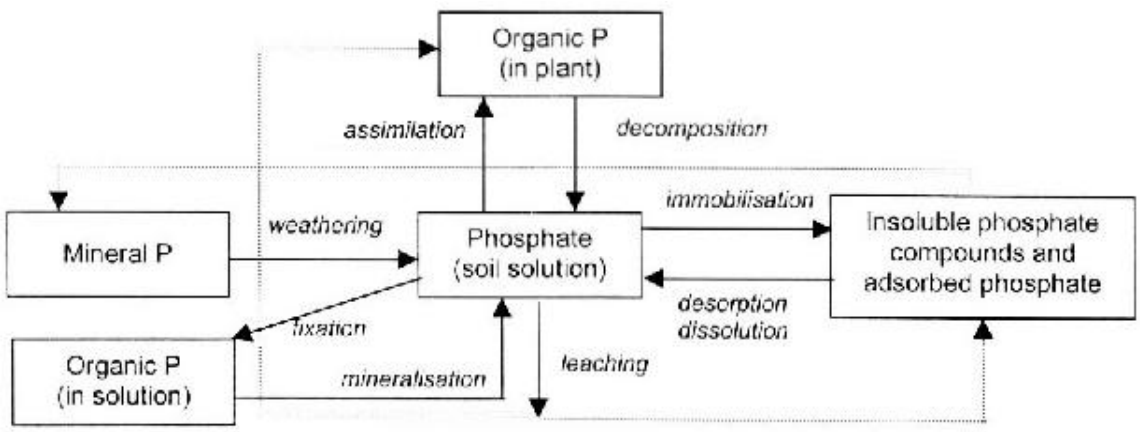


Fig. 12. The phosphorus cycle.

As with the nitrogen cycle, the phosphorus cycle is a complex set of relationships, but one particular relationship is vital for the phosphorus cycle to occur, as is explained in the following story: *When plant met fungi*.

When plant met fungi

This is the story of an association that plants need in order to have access to enough water and dissolved nutrients. I believe this is a key to making farms drought-tolerant.

There are a type of fungi known as **mycorrhizae**. These microorganisms have a very close relationship with plants. Like the bacteria in the legume relationship, fungi cannot make their own sugars, and since all living things need sugars (carbohydrates) for body parts and for the energy to drive respiration, the fungi needed to develop relationships that would be beneficial for their own growth and survival.

In the beginning, fungi had several options, they could have evolved into predators and hunted other organisms that eat plants or algae; they could have evolved into herbivores, feeding on plants or algae; or they could have evolved into decomposers, feeding on dead organic matter. The mycorrhizae fungi, however, developed another type of relationship: a symbiotic, or mutually beneficial relationship.

All the while, plants faced challenges of their own. They could make plenty of sugars, to store energy for respiration, but in order to turn the carbohydrates into many different body parts they needed elements from the soil, such as nitrogen and phosphorus. Plants were also colonising dryer areas of land and were having great difficulty getting access to enough water.

The nitrogen plants needed was being made available through associations between bacteria and plants, such as legumes, as well as through many blue green algae (**cyanobacteria**) associations. Fungi could not fix nitrogen but had their own special ability. They could dissolve phosphorus from soil by excreting acids and enzymes onto soil particles and releasing the phosphorus in a soluble form. This is something water could not do alone.

Fungi have another special ability. Although they are microscopic, fungi are not single cell organisms. They can join their cells together and form chains (**hyphi**). They can also grow into mushrooms when it is time to reproduce.

These tiny hyphi chains, like a microscopic root system, were able to get into every available space in the soil and between soil particles. So, the fungi could gain access to water that plant roots were too big to get to.

It was like a match made in heaven when plant met fungi and they touched for the first time…

Suddenly, sugars started flowing into the fungi cell from the plant cell, and water, full of dissolved phosphates and other nutrients, started flowing from the fungi cell into the plant cell. Neither the plant nor the fungi needed to input any energy for this exchange to occur and, in fact, it meant both needed less energy for survival.

The plant now had much greater access to water and the high concentration of dissolved nutrients within it. The fungi could access as much sugar as they needed without having to hunt other organisms, eat plants or algae, or decompose dead organic matter. The two now worked as though they were one and the fungi became an extension of the plant's own root system.

For a long time, the mycorrhizal association between plants and fungi existed in peace and harmony, with each evolving to rely on the other. Many other organisms thrived in the root zone of this great relationship, where sugars, nutrients and water were abundant. Those organisms too, evolved relationships with each other and spread the bounty throughout the environment. Until one day, when a man sprayed fungicide onto the soil…

☯ Soil structure and water holding capacity

Soil fertility is a result of the activity of organisms functioning in and on the soil, facilitating the nutrient cycle. The higher the level of organism activity, including birth, death and decomposition, the higher the level of fertility. The more complex the web of relationships is between organisms, the more organism activity there is, and the quicker the nutrients cycle. Therefore, the levels of soil fertility and biodiversity, and any fluctuations, are directly related.

Soil structure is also related to levels of organism activity, in particular the production of humus. Humus is the final broken down component of organic matter. Humus molecules, which have been processed through the activity of microorganisms, combine with many other humus molecules to form humus particles.

The humus particle is the key component of soil structure. Without humus, soil is just a collection of broken down pieces of rock. Humus particles form the organic structure that gives life to the soil.

Soil fertility increases as soil structure builds. Soil structure builds as organism activity increases. Organism activity increases with an increase in the complexity of relationships. The complexity of relationships increase with an increase in biodiversity.

One of the functions humus performs within the soil is binding the inorganic sand, silt and clay particles together, like organic glue. This enables the soil to develop ped formation, the indicator of good soil health. Peds are the small clumps that you see soil break up into, for example, when you disturb fertile soil in a natural environment.

Fig. 13. Picture of a sample of topsoil with ped formation (pedal soil).

Peds give the soil excellent aeration, infiltration and drainage properties, and greatly increase the water-holding capacity of the soil. This is because the clumps of soil are all separate soil structures with the cracks between them providing excellent passageways for air and water to move through. The peds themselves can absorb and hold moisture while the cracks between them allow excess water to drain away.

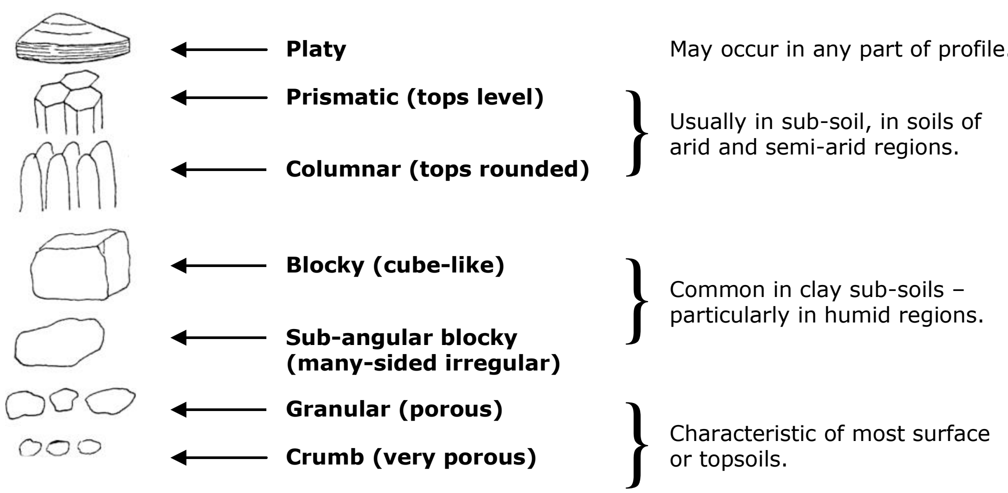


Fig. 14. Soil structural types.

Humus is the most effective component within soils for holding water, due to its tiny size and highly irregular shape. These two properties give humus particles their massive surface area, many times greater than clay, providing vast areas within the soil, for water to adhere to. The amount of water that can be held within soil after gravity has drained away the excess, is called **field capacity**. For water to resist gravity it must be stuck to something solid. The higher the humus component is within the soil, the larger the surface area and greater the field capacity of the soil.

Another important function of humus is its ability to store excess nutrients in the soil. Humus has a very high **cation exchange capacity**, many times greater than clay, due to its massive surface area and the many negatively charged sites that cover its exterior. Positively charged nutrients are attracted to the humus particles like pins to a magnet, where they are held tightly enough to resist being leached away into the drainage water. When the concentration of nutrients in the soil water becomes less than that held on the humus particle, the nutrients move away from the humus particle and back into the soil water, ready to be taken up by plants and microbes.

The large, moist surface area of humus particles provides the ideal environment for biological and chemical reactions to take place. Microbe respiration and chemical reactions that facilitate the nutrient cycle increase dramatically when the level of humus content is high. The higher the humus content the higher the soil fertility.

☯ The water cycle and Equilibrium

All the processes that occur within a natural ecosystem, as explained above, are completely reliant on water. Water is needed to erode rock into soil, to combine with carbon dioxide to form carbohydrates, to dissolve nutrients, to transport nutrients through their cycles and to facilitate chemical and biological reactions. The most important function of water, however, is the medium it provides for distributing energy throughout the environment.

Water has amazing properties that allow it to absorb huge amounts of energy (heat) and then re-distribute that energy throughout the environment. The high thermal mass of water, its high boiling point and its liquid state at room temperature are the key properties that facilitate this energy exchange.

As mentioned previously, water is the limiting factor that determines the final plant succession. As plant communities develop, they increase in disorder through an increase in diversity and layering. This is an indication that the ecosystem is moving towards equilibrium. Equilibrium is the state of greatest disorder (**maximum entropy**). A system can only move towards equilibrium if the amount of energy entering the system is less than the amount being released, therefore, there is a correlation between the amount of water in the system and the amount of energy capable of being released.

If the input of energy into a system is greater than the release of energy, that system will move away from equilibrium, and become more ordered. A desert is very ordered compared to a rainforest, as deserts have high energy inputs from the sun and/or wind, and little water available to help release that energy from the system. Rainforest, on the other hand, may have started out with energy inputs equivalent to that of a desert, but had sufficient water available to release energy at a greater rate than it receives. As the layering of vegetation increases, there is a decrease in wind and sun exposure, reducing the energy inputs and allowing the system to move more easily towards equilbrium.

Water distributes energy through the cycles of **condensation** and **evaporation**. As energy enters a system, the water molecules absorb that energy and begin to vibrate. If energy entering the system is greater than the amount of energy the liquid water can absorb, then the water molecules evaporate. This process absorbs energy (heat) from the surface it evaporated from. The water molecules are now in a gaseous state and can rise up and away from the system carrying with them some of the energy from that system.

These water molecules will be moving to places of lower energy (colder) where they will condense back into their liquid state and release heat during the process. The heat has now been removed from an area of high energy to an area of low energy (moving towards equilibrium).

Note: The uneven distribution of heat over the earth and the process of moving towards equilibrium is what creates our weather patterns and ocean currents.

Equilibrium is the driving force of all energy movements in the universe. The balancing of any uneven distributions of energy is the process of moving towards equilibrium. This is an automatic process that releases energy. To move a system away from equilibrium, or to maintain a system out of equilibrium, there needs to be an input of energy.

Diagrams

Fig. 3. Layering in a rainforest
adapted from Bate, J. & McMahon, R. Factors Affecting Vegetation Patterns NSW Dept. of Technical and Further Education: Division of Horticulture.

Fig. 11. The nitrogen cycle.
adapted from Fullick, G. (ed.) Soil Science – Practical Manual 6724W Hunter Institute of Technology: Department of Chemical Food & Environmental Technology. p.39.

Fig. 12. The phosphorus cycle.
Fullick, G. (ed.) Soil Science – Practical Manual 6724W Hunter Institute of Technology: Department of Chemical Food & Environmental Technology. p.41.

Fig. 13. Picture of a sample of topsoil with ped formation (pedal soil).
Fullick, G. (ed.) Soil Science – Practical Manual 6724W Hunter Institute of Technology: Department of Chemical Food & Environmental Technology. p.20.

Fig. 9. Single-celled green algae (left); and multi-celled section of Hakea leaf (right).
&
Fig. 10. Table of biologically important molecules (carbohydrates and proteins).
Knox, B., Ladiges, P. & Evans, B. (1994) Biology McGraw-Hill Book Company Australia Pty. Ltd., Sydney (algae cell p.114; Hakea leaf cells p. 752; table of molecules p.11).

Fig. 6. An example of natural succession.
NSW Dept. of Technical and Further Education: Division of Horticulture Botany 2

Fig. 8. The hydrological cycle.
adapted from Sale, C. (1967) World Water in Environment & Development. Shakespeare Head Press, NSW. p.61.

Fig. 14. Soil structural types.
Thomas, A.M.D. Dept. of Technical and Further Education: Division of Horticulture Plant Growing Media: Book 1 p.29.

Fig. 4. Common leaf adaptations of heath plants.
Wrigley, J.W. & Fagg, M. (1979) Australian Native Plants. William Collins Publishers Pty Ltd, Sydney. (wattle, p.240; grevillea, p.273).

Fig. 5. Common leaf adaptations of rainforest plants.
Wrigley, J.W. & Fagg, M. (1979) Australian Native Plants. William Collins Publishers Pty Ltd, Sydney. (lilly pilly, p.289; rainforest, p.49).

Fig. 1. Soil food web.
from www.soilfoodweb.com

Fig. 7. Habitat in a natural environment.
Gosford City Council (2005) Little Green Steps: Wildlife Resource Kit

Fig.2. Diagramatic interpretation of predator-prey population fluctuations in relation to levels of diversity over time.
Author’s interpretation.