Section Four

Soils

Contents

Parent Material of Soils

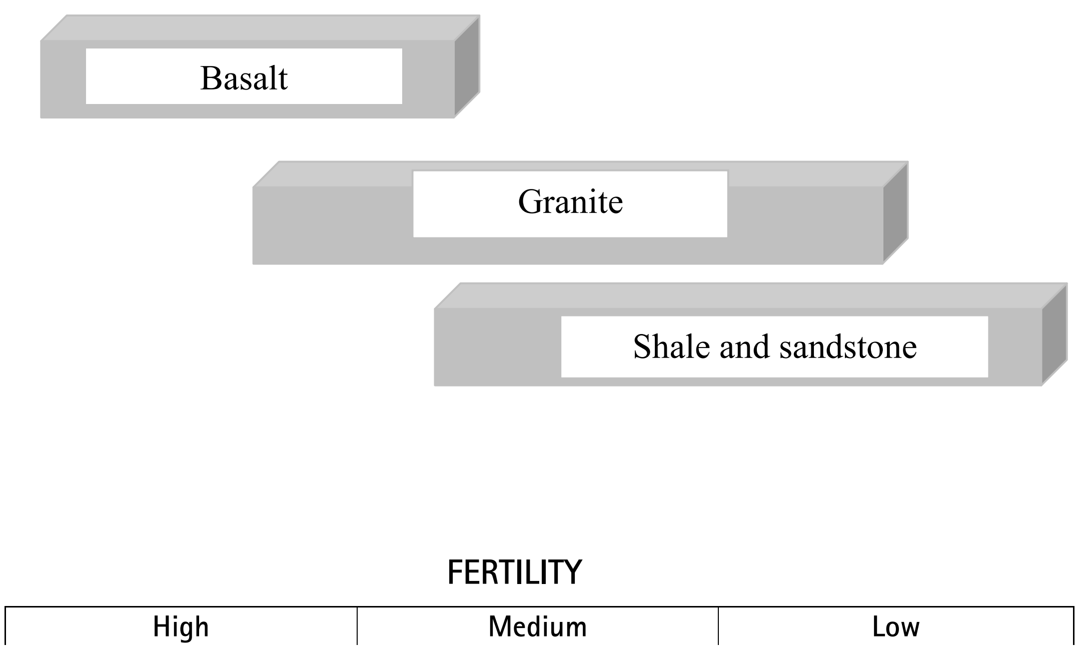
Three Different Classifications for Rocks

Igneous
These are the primal rocks originating from molten mixtures which over the space of many eons in time solidified. Many of our silica rock powders will be found originating in this group. Igneous rocks are formed from the action of heat. For example, granite soils which are formed from the hardening of various kinds of molten rock material and are composed of the minerals quartz and feldspar among others.

Sedimentary
These rocks are extremely varied, differing widely in texture, colour, and composition. Nearly all are made of materials that have been moved from a place or origin to a new place of deposition. The distance move may be a few feet or thousands of kilometers. Flowing water, wind, waves, currents, ice and gravity move materials on the surface of the earth by action that takes place on or very near the surface. Sedimentary rocks are composed of fragmented rock material that has been transported and deposited by wind, water or glaciers. Limestone, sandstone and shale are examples.

Metamorphic
These are rocks which have been changed from their original. Changes may be barely visible, or may be so great that it is impossible to tell what the original rock once was.

Influence of Parent Rock on Soil Fertility



Soil Facts

- Soil is a living system.
- Soil contains 0.01% of the Earth's water.
- Soil is 49% Oxygen, 33% Silicone, 7% Aluminium, 4% Iron, and 2% Carbon.
- 50% of the soil is air and water. The rest is mineral and organic material.
- In one gram of soil the number of bacteria ranges from 100,000 to several billion.
- There are 5000 to 7000 different species in one gram of soil.
- The total living matter in an acre of soil ranges from 5000 to 20,000 pounds.
- Each year, 15 tons of dry soil per acre passes through earthworms. Earthworms eat soil to get the organic materials in it. The rest passes through them.
- About 42 centuries ago, the Chinese used a soil map to determine taxation amounts.
- Soil develops from geological materials such as rocks, glacial deposits, granite, limestone and stream sediments.
- Soil is much like the earth's peel, just like an orange peel.
- Erosion of soil from our lands clog rivers and dams and decreases the usefulness of soil for growing plants.
- Soil is often at the bottom of the food chain. Plants and small invertebrates feed off of the soil and animals feed off of the plants.
- Soil is used to absorb wastes.
- Over 1.1 billion pounds of pesticides worth 25 billion dollars are used each year, much of it ending up in the soil. That is over 4 pounds per person.
- Cleaning up toxic chemicals in the soil and water has cost $20 billion over the past 15 years in the United States.
- Cleaning up the rest of the toxic chemicals already in the environment would cost $500 to $2500 per person.
- The United States has at least 36,000 hazardous waste sites present in our soils.
- Soil supplies the water and nutrients necessary for plant growth. Around one acre of land is used to supply the food for each person in the world.
- An acre of corn gives off 4,000 gallons of water a day in evaporation.
- Soil needs to provide 4,000 gallons of water to grow one bushel of corn and 11,000 gallons of water to grow one bushel of wheat.
- Soil influences the life span of our roads and highways.
- The stability of the foundations of our houses and buildings are determined in part by the soil they rest on.
- Soil makes excellent mud pies.

A pea sized lump of soil contains:

- 10 million to 10,000 million bacteria
- 100,000 to 10 million fungi spores
- 100,000 to 1 million protozoa
- 10 to 10 million algae

Importance of Good Soil

Good soil is the basis of our existence — humans depend on humus. Without it there can be no genuine health, education, social order or individual spiritual growth. Humus maintains the purity and supply of fresh water. It contributes to plant vitality, animal health, human intelligence through proper nutrition, social justice, economic sustainability, and above all to personal independence in that people can access the basic resources with which to provide for themselves. Through its emphasis on soil building, Bio-dynamic agriculture affects all these realms of life.

Elizabeth Alington, Sourced from *Harvests,* Volume 59, No. 1., New Zealand BD Association

Importance of Clay

"Constellation forces do not come to the earth directly, but are reflected by the Moon and the Sun. Clay picks up these reflected forces emanating from the constellations…

"Clay can be either paramagnetic or diamagnetic. When the Sun is shining, it is paramagnetic. When the moon is shining it is diamagnetic. Sometimes both the Sum and the Moon are shining at the same time, in which case the clay is diamagnetic. Sometimes, neither Sun nor Moon is shining, in which case the clay is not active. For now, it is enough to recall that clay acts as a catchpen for influences passed along by the Sun and the Moon acting as reflectors for the constellations.

"This is what Steiner meant when he told us that clay is a means of transport. Certainly, clay assists silica rock powders in moving plant saps from roots to leaf areas and assisting the "lime" rock powders in moving the saps from the leaf areas back to roots. Since the forces in both the silica and "lime" rock powders are dependant upon the Sun, clay rock powers are the only ones working at night, or when the Moon is shining. More accurately, the Moon does not need to shine. It may be in the dark of the Moon, but the Moon is still in the sky reflecting the forces from the constellations. Cloudy days or cloudy nights do not compromise transmission of cosmic forces.

"… this attribute emphasises again and again the value of paramagnetic clay rock powders in maintaining a healthy sap flow in trees and corn in particular, and in plants in general.

"Sap circulation is important or maintaining cold resistance, drought resistance and insect and disease resistance.

"Clay has been known for centuries. It has been used by many peoples for its healing properties. I feel certain that these healing properties are due to its paramagnetism. We can truly say that paramagnetic clay is an enlivened rock powder deriving its beneficial healing properties from its relationship with cosmic bodies. And the cosmic bodies carry healing forces which can be transmitted by the proper paramagnetic clays."

Harvey Lisle, *The Enlivened Rock Powders*, pgs59, 60, 64, 70

Clay's Attraction

"Clay has a negative electrical attraction for most particles that are positively charged. In the organism most of the toxic poisons are positively charged. These toxins are irresistibly drawn towards the clay. Moreover, according to an authority on Bentonite (another name for the energetic clay) "clay's particles being shaped like a 'calling card' with the wide surfaces negative and the edges of the card positive have many times more negative than positive pulling power."

"The same authority writes the following: "The very minuteness of the particles of Bentonite gives a large surface area in proportion to the volume used, thus enabling it to pick up many times its weight in positively charged particles." According to Robert T. Martin, B.S., University of Minnesota, Ph.D., Cornell University, and mineralogist at Massachusetts Institute of Technology, one gram of this product has a surface area of 800 square meters. The greater the surface area the greater is the power to pick up positively charged particles."

Michel Abehsera, *The Healing Clay*

Use Clay to Improve Sandy Soils

Incorporation of Clay on Sandy Soils

"In my pursuit of a permanent soil fertility that can be maintained with fewer inputs, I have added clay (specifically, montmorillonite/bentonite types) directly to the soil in my greenhouses. I spread the clay layer on top of a layer of peat moss (for long-lasting organic matter) and till them in together. That practice was inspired by Michigan State research[1] which indicated impressive improvements in yield, moisture retention, and nutrient availability on sandy soils amended with montmorillonite clay. Montmorillonite has the highest cation exchange capacity (CEC) of all mineral soil components. Investigations of soils that suppress soil-borne plant diseases have found the common thread to be their content of montmorillonite clay. But, best of all, I like the idea of making a permanent addition to the soil, one that will effect a long-term improvement rather than a short-term stimulus.

"Adding clay to sandy soils was a common practice in Europe and, to a lesser extent, in the U.S. in centuries past. Henry Coleman, who investigated the practice thoroughly in his 1846 book, European Agriculture and Rural Economy, refers to the soil improvement by claying as being of a "substantial and permanent character." Coleman describe his visits to different farmers who were spreading clay at rates between 25 to 100 tons to the acre. Every one of them attested to the benefits of the practice in terms of higher yields and the higher quality of the produce. On one farm belonging to the Duke of Bedford, clay had been spread on a total of 420 acres. The common technique was to distribute the material on grassland or plowed fields in the fall, let it become well pulverized by winter freezes, and then incorporate it with a harrow in spring. Those spreading clay at the lighter rates noticed additional improvements if the application was repeated after 20 years time.

"Since I have a preference for correcting causes rather than treating the symptoms of a problem, I am very interested in permanently correcting the low initial fertility of my sandy soil by adding clay. I can justify the use of purchased montmorillonite (at 10 tons per acre) on my greenhouse soils because they are cropped intensively over a long season. But the cost would be prohibitive if I wanted to do my outdoor fields. The opportunity to spread clay on the outdoor fields came after we had dug an irrigation pond. When we were planning the pond, I knew I would have uses for the peatlike, muck soil from the top layer. I further assumed, and rightly so, that the gravely underlayer would be perfect for building farm roads. However, I was pleasantly surprised when huge piles of a rich, blue marine clay appeared from the deeper layers. I emulated the good Duke of Bedford, albeit on a much smaller scale, spreading it on my fields and leaving it over the winter before incorporation. The difference in crop yield and quality was apparent right from the start, especially with the onion family, which had never appreciated our sandy soil, and it looks like a permanent improvement."

Coleman, E., *The New Organic Grower,* Chelsea Green Publishing, White River Junction, VT 05001, pp116,117, 1995

[1] M.M. Mortland. A.E. Erickson and J.F. Davis, "Clay Amendments on Sand and Organic Soils," Michigan State University Quarterly Bulletin, 40:1 (1957), pp. 23-30. A more recent study confirms those results: Gerhard Reuter, "Improvement of Sandy Soils by Clay-Substrate Application," Applied Clay Science, vol 9 (1994), pp 107-20.

Using Montmorillonite Clay

"In order to enhance the decomposition process and the quality of the resulting compost, I incorporate 1 to 2 percent by weight of a montmorillonite-type clay with the forage crops in the windrow.

"Montmorillonite is an expanding-lattice clay that has been determine to have both biotic and abiotic effects in aiding the conversion of organic matter into stable humus.[2] The resulting clay humus faction that develops is very beneficial to soil fertility and plant growth. Montmorillonite (also sol as Wyoming bentonite) is mined for numerous industrial and agricultural uses. I have obtained my supplies either through the livestock feed industry, where it is used as a binder for pelleted feeds, or directly from wholesalers."

Coleman, E., *The New Organic Grower,* Chelsea Green Publishing, White River Junction, VT 05001, p115, 1995

Clay Spreading (Sandy Soils)

Incorporation of 100 tonnes/ha clay can increase water storage of the top 10cm leading to increased yield. This effect has been observed to last 30 years and is estimated to still be going strong after 100 years. Clay spreading also provides the extra benefits of:

- increasing soil pH
- decreasing nutrient leaching
- improving soil wetting for germination and emergence.

Sourced from *http://www.bettersoils.com.au/fact_sheets/fs_4.htm*

Soil Organisms

Conditions Required for Soil Organisms

Most soil organisms are very sensitive to changes in soil moisture and temperature. As the plant roots and the soil organisms consume air, a good air circulation within the soil is crucial for their development.
Soil organism activity is generally low when;

- soils are dry
- very wet
- or too hot.

Activity is highest;

- in warm soil
- moist soils
- when food (i.e. biomass) is available.

IFOAM Training Manual for Organic Agriculture in the Tropics, 2003, Complied by FiBL, ISBN 3-934055-25-7

[2] Some background on this topic can be found in P.M. Huang and M. Schnitzer, eds., "Interactions of Soil Minerals with Natural Organics and Microbes," SSSA Special Pubn., No 17 (Madison, WI: Soil Science Society of America, 1986).

Importance of Soil Organisms

Soil organisms are important because they;

- help to decompose organic material and build up humus
- mingle organic matter with soil particles and thus help to build stable crumbs
- dig tunnels, which encourages deep rooting of plants and good aeration of the soil
- help to release nutrients from mineral particles
- control pest and disease organisms affecting the roots of crops
- improve soil structure
- fix nitrogen from the air
- improve water infiltration
- convert elements into a form able to be taken up by plants
- benefit some plants through symbiotic relationships between micro-organisms and plant roots.

Soil Organisms

Soil micro-organisms are the key elements to the quality and fertility of soils but for us humans they do their work invisibly. The greater the variety of species and the higher their number, the greater is the natural fertility of the soil.

Soil organisms are just like any other living organism - they have similar requirements viz. food and habitat. Every time we add organic matter in the way of compost, green manure crops, mulch, etc., we are providing both of these essentials. The emphasis throughout this series of articles on the soil has been the importance of the 'health' of the plants, the animals and us as the end consumer. The regular and continuous addition of organic matter to the soil increases the diversity, population and activity of soil organisms. Our aim should be to ensure the conditions are suitable for these invaluable organisms, many of which are invisible to the naked eye.

Hunter BD Association, *Biodiversity, Special Issue*, 2003, pp 27, 28.

Benefits of Soil Organisms

- fragmenting organic residues
- decomposing organic matter
- cycling nutrients
- mineralising nutrients
- storing nutrients
- improving nutrient availability
- assisting in the formation of soil aggregates and pore spaces
- improving soil structure
- stabilizing the soil
- some have symbiotic relationships with plant roots
- some regular the populations of other soil organisms
- whilst some transmit diseases, some regulate disease
- some assist in breaking down pollutants
- some fix nitrogen from the atmosphere.

All soil organisms have their functions and what we as farmers and gardeners are aiming for is diversity in both species and numbers.

Sandra Norman, Sourced from Hunter Organics

Macro Organisms or the Physical Decomposers

Earthworms: the 'king' of recyclers - the castings of the humble earthworm are rich humus, full of plant nutrients held in a stable form for plants to use. This type of humus encourages fine root hair to develop on plant roots, essential for the uptake of nutrients.

Millipedes: eggs laid in the soil - adults feed on plant material, breaking it down

Centipedes: feed on living animals such as insects and spiders

Ants: assist with the aeration and water infiltration through the tunnels left behind as they transport material to their nests

Termites and Slaters: some species not necessarily desirable near buildings, but they play an important role in decomposing dead wood - integral for the health of the 'bush'. The soil is opened up as they transport material to their nests

Spiders: useful for pest control - feed on insects and small invertebrates

Beetles: numerous varieties - some feed on fungal spores; others feed on insects, snails, etc; others feed on decaying vegetable matter

Springtails: feed on fungi, decomposing plants

Nematodes: not all nematodes eat plant roots - some feed on other organisms such as fungi, bacteria, algae, other nematodes, etc.

Mites: some feed on plant matter whilst others ingest nematodes, fly larvae, other mites, etc.

Micro Organisms or the Chemical Decomposers

Bacteria: tiny, single celled organisms feeding on organic matter with the nutrients that are released available for plants; other types of bacteria feed on other soil life, particularly fungi; some bacteria can also fix atmospheric nitrogen

Actinomycetes: usually more active in the later stages of decomposition as they are able to break down the more difficult parts of organic matter. Some produce chemical substances (antibiotics) that kill nearby organisms including parasitic fungi. Other actinomycetes have a symbiotic relationship with some plant species (e.g. Casuarina sp.) forming nitrogen nodules on the roots.

Protozoa: Includes springtails, beetles, ants, spiders, mites, centipedes, millipedes, scorpions and termites. These shred large pieces of organic matter – increasing the surface area which in turn stimulates bacteria, speeding up decomposition; mix the soil; create 'tunnels' as they burrow, improving soil structure; are predators of other soil organisms; keeping populations under control; stimulate the growth of fungi.

Fungi: most fungi live on dead organic matter and are present in high numbers during the final stages of decomposition. Soil structure is improved - they produce humus and as well as bind soil particles together. Some fungi are parasitic and feed from living plants. Fungi form symbiotic relationships with the roots of some types of plants – this relationship increases the surface area in the root zones for the uptake of nutrients; improves soil structure by physically binding soil particles into aggregates; food for other soil organisms; reduce leaching of nutrients from the root zone of plants.

Continued over page

Algae: tiny plants, some fix atmospheric nitrogen. Increase soil organic matter levels; fix atmospheric nitrogen – require sunlight and moisture – are generally near the surface.

It may appear that some of these organisms are consuming what could be viewed as 'beneficials', however it is the overall balance of the food chain that is relevant and a well managed organic garden should readily achieve this natural balance.

Mycorrhiza – A Beneficial Fungus

Mycorrhizae live in association (symbiosis) with plant roots. Both the plant and the fungus profit from the association; the plant gets nutrients collected by the fungus and the fungus receives assimilates ('food') from the plant in exchange. Mycorrhizae are present in all types of soils, but not all crops can get into a symbiosis with the fungus.

Mycorrhizae fungi have several functions, which are of high interest to the farmer:

- They enlarge the rooting zone of plants and can enter into small pores
- They dissolve nutrients such as phosphorus from mineral particles and can carry them to the plant
- They make soil aggregates more stable thus improving the soil structure
- They preserve moisture and improve the water supply to plants.

Mycorrhizae formation depends on the soil conditions, the crops that are grown and the management practices:

- Soil tillage and burning of biomass drastically harm the mycorrhizae
- High nutrient levels (especially phosphorus) and chemical pesticides suppress the symbiosis
- Mixed cropping, crop rotation and the cultivation of perennial plants encourage mycorrhiza
- Practice mulching to stabilise soil temperature and moisture.

VAM Fungi and Their Role in Agriculture

From a thesis on The Ecology of Fungi in Contrasting Australian Systems, Megan Helen Ryan, Dr. of Philosophy, Australian National University, 1998, (overview by Cheryl Kemp).

Vesicular-arbuscular mycorrhizas (VAM) are formed by fungi in the order of Glomales (Zygomycotina). VAM fungi produce a diffuse network of hyphae in the soil, which is connected to internal hyphae in the cortex of the host root. The external hyphae absorb nutrients from the soil and these are transported into hyphae in the root and absorbed by the host plant. In return, the VAM fungi have access to carbon compounds photosynthesised by the host plant: the primary energy source for the fungi. VAM colonization may lead to significant increases in host plant growth, due to the fungi increasing Phosphorus (P) uptake by the plants. Phosphorus is required by plants in relatively high amounts, but often occurs in soils in low concentrations and in insoluble forms not accessible to plants. VAM fungi can extend past the depletion zones around the roots, and absorb P and transport it to the plants faster than P can move through the soil solution. Overall, the presence of VAM fungi substantially increases the volume of soil from which a host plant can access P.

Continued over page

If P is applied to the soil, the proportion of root length colonized and number of spores produced generally decreases. High P values and low light levels also greatly reduce VAM colonisation. VAM hyphae are also thought to colonise and connect roots of different species and may enhance recycling of nutrients within a plant community and reduce nutrient leaching, by transferring nutrients from dying plants, to neighbouring plants.

In natural systems, VAM fungus' primary benefit to the plants is protection against pathogens.

They may also be an important food source for many soil organisms and contribute to the maintenance of soil structure through assisting the formation and stabilisation of soil aggregates.

Grasses with fine roots and long root hairs, gain little benefit from VAM fungi, but legumes, with thicker roots and fewer root hairs exhibit a larger growth response to VAM colonisation. The high P requirement for nodulation in legumes may also increase dependency on VAM fungi.

Some plants have marked increase in growth due to VAM fungi, such as cotton, and VAM fungi colonise many major crop and pasture species including wheat, barley, sunflowers, linseed, peas, clover and medics. Some crops are non-mycorrhizal including lupins, crucifers and canola, and rye grass may not react positively to colonisation to VAM fungi.

This part of being able to manipulate the amount of VAM fungi is important to the alternative farmer, as some crops need a rotation to clear VAM fungi out before growing another crop, such as tobacco and soybeans which need a low P level to have high RVA levels.

Fescue (*Festuca arundinacea)* is a host to the endophytic fungus *Acremonium coenophialum,* which produces metabolites toxic to VAM fungi. It is possible that VAM populations could be manipulated with fescue varieties which are either susceptible or non-susceptible to the endophyte. Inclusion of non-VAM brassicas (e.g. canola) in rotations could also be used to reduce VAM inoculum potential of soil, and inclusion of highly colonised legumes as crops or pasture components could be used to increase VAM inoculum potential.

Other factors which affect VAM levels are long fallows, when levels of VAM colonisation become much lower, and this is responsible for reduced growth of crops. Addition of soluble P reduces VAM colonisation and the influence of fungicides and herbicides was listed as variable.

The author feels that the contribution of VAM fungi to agricultural systems may not be reflected in short term crop yields. By influencing nutrient cycles, contributing to the maintenance of soil structure, providing energy (hyphae) to the soil ecosystem and through interacting with pathogens, VAM fungi may contribute to the long term sustainability of agricultural systems. Their presence may be vital if functional low-input agricultural systems are to be developed.

Earthworms

The Earthworm - an invaluable helper
Break-down organic matter and minerals; mix the soil by taking organic matter further down the soil profile and bringing soil from deeper in the soil profile to the surface; improve soil structure in a number or ways; aerate the soil; improve water infiltration and retention; improve drainage of the soil; bind soil particles into aggregates. Also worm casts (excrement) are a form of soil aggregate.

Benefits of earthworms;

- sign of a fertile soil
- they accelerate the decomposition of biomass
- remove dead plant material from the soil surface
- they mix organic and mineral soil particles
- build stable crumbs
- help improve the soil structure
- their excrements contain 5x more nitrogen, 7x more phosphate, 11x more potash and 2x more magnesia and calcium than normal earth
- their tunnels promote infiltration and drainage of rainwater
- thus prevent soil erosion and water logging.

Good Soil Husbandry

Practices of good soil husbandry include:

- retaining organic matter
- appropriate cultivation
- good crop rotations
- using deep rooting and nitrogen-fixing plant species
- protecting the surface
- avoiding compaction by machinery and animals
- regular use of the biodynamic preparations
- maintaining pH
- preventing soil erosion
- maintaining good soil aeration.

IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

Soil Conditions

Indicator Species for Soil Conditions

Perceptive observation and ongoing monitoring can be a powerful tool for making management decisions when looking at managing or modifying existing pastures. Species present can be useful indicators.

Feature	**Indicator Species**
Acid soils	Natural timber type e.g., Peppermint, Ironbark, She oak
Low soil fertility	Sorrel, Wire grass
High soil fertility	Barley grass, variegated thistle.
Wet and waterlogged areas	Rushes, Yorkshire fog
Saline areas	Couch, Sea barley grass. Loss of some species (e.g., White clover, Cocksfoot).
Heavy grazing/set stocking	Yorkshire fog, Tussocky poa
Overgrazing and destabilised pasture	Loss of perennial species. Poor ground cover in the summer. Invasion by annual weeds, e.g., thistles, Vulpia
Low soil fertility	Sorrel, Wire grass

Reference: *Ecology for Organic Farmers NSW Agriculture.*

Soil Structure

The most highly structured soils are generally formed where clays with high calcium levels and low sodium levels are present; high levels of sesquioxides (as indicated by the presence of free iron and aluminium oxides); and/or high organic matter and soil fauna activity (particularly critical for lighter-textured soils). These attributes become more common in soils as the parent material becomes increasingly mafic in character (but not ultramafic). Soils with good structure, at least in surface units, are commonly formed from parent materials of mafic to intermediate composition (e.g. basalts and andesites) while more weakly-structured soils are typically formed over the more siliceous parent materials (e.g. granites and sandstones).

Soil structure is formed through plant roots and their associated bacterial life as they move and bind soil particles together. Clay is a cohesive agent that also helps to bind soil together. Weather changes such as wetting, drying and freezing also help in forming soil structure through shrinking and cracking of the soil but improvements can only be sustained in the presence of good plant root formation.

Soil structure is very important for plant growth because:

- it affects the movement of air
- it affects the amount of and availability of water
- its strength affects the movement of roots, seedlings and worms
- it affects nutrient retention
- it affects the movement of heat in soil
- it determines how readily the soil will be eroded
- it determines how easily the soil can be cultivated.

Features of soils with good structure are that they remain unchanged in crumbs (loose peds) and are not sticky when wet and do not form large clods or hard crusted surfaces when dry.

An Ideal Soil Structure

"In good soils, the individual particles of sand, clay and silt will naturally group together into larger units called granules or aggregates. This process is necessary to a good soil, since it promotes aeration and water drainage. And the success of soil in forming these aggregates is called its structure or crumb structure. Sandy soils will have poor structure, since sand is too coarse to form aggregates, while a heavy clay soil compacts when wet, inhibiting plant growth.

"An ideal structure is one which contains large pore spaces to aid drainage, percolation of the air and penetration of roots, yet at the same time provides clusters of small pores capable of retaining an adequate reserve of soil moisture for plant growth.

"Soils which have been chemically treated with little or no addition of organic matter will gradually lose structure, necessitating increased fertilisation, cultivation, and irrigation, and will be more prone to erosion, with wind and water carrying away valuable topsoil. A strongly structured soil, on the other hand, is able to retain its crumbly texture even after repeated cultivations, and has the strength to resist compaction. It will show quicker recovery after drought or a prolonged wet spell."

Gita Henderson, *Harvests,* NZ BD Association, Vol 58, No. 1, p4, 2005

Humus Increases the Water Holding Capacity of Soils

Water-Holding Capacity Increase for One Hectare for Varying Levels of Humus Increase

*Using the guidelines ratio, which has been established for additional water retention the following gains can be expected.

Humus Increase	Increase Volume of Water Retained / ha (to 30 cm) (OC% x 4,000,000kg x 4)
0.5%	80,000 litres (average 2004 levels)
1 %	160,000 litres
2 %	320,000
3 %	480,000 litres
4 %	640,000 litres
5 %	800,000 litres

*The Clarence Valley catchment has an area of 2,300,000 ha, a 0.5% increase in humus (organic carbon) would therefore store an additional 184,000,000,000 litres of water following an adequate rainfall event.

Glenn Davis Morris, Faculty of Rural Management, The National University of Sydney, July 2004
author of Sustaining National Water Supplies by Understanding the Dynamic Capacity that Humus has to Increase Soil-water Storage Capacity, a dissertation completed in a holistic style which reflects the wider knowledge base necessary for study into sustainable agriculture, and was submitted in partial fulfillment of the requirement for the degree of Master of Sustainable Agriculture.
Extract from Acres Australia, Vol 15, No.2

Soil Colour

Colour changes and texture are often enough for experienced people to understand much about how that particular soil was formed and how it will behave. The colour of the soil often tells you a lot about its fertility. Light-coloured soils are mostly low in nutrients while dark-coloured soil often indicates a high level of organic matter and also a higher nutrient level and water holding capacity.

Soil Cultivation

Aim of Soil Tillage

The aim of tillage is 'biological enhancement', i.e. to improve the balance of decomposition and synthesis or of humification and mineralisation, and enhance productivity. It serves to improve the physical texture of the soil, stimulate the whole range of biological and chemical processes and create the conditions of good tilth. In the final instance it is the biological activity of the soil that determines soil structure and its permanence and resistance to unfavourable influences such as heavy precipitation, the weight of machinery, and so on.

Tillage stimulates microbial activity and therefore humus decomposition and also causes temporary loss of soil structure as the natural soil stratification is destroyed. At the same time the chaos created in a previously well ordered system offers potential for heat, light, air and cosmic forces to intervene and establish new conditions.

Many soil organisms will be destroyed by deep turning and the mixing of the levels, but rapidly multiply again when conditions are favourable. Activity in fact will be higher than prior to ploughing.

Tillage should be as infrequent as possible.

Elementals; BD Tasmania, p8, No.80, Dec 2005

To Dig or Not to Dig?

A well structured soil is one that contains rubbly particles of various sizes which are loosely held together, with many air pockets, which will break up easily into natural portions. Imagine a cake baked with baking powder – it has many air pockets and it crumbles easily. Now imagine a cake which you forgot to add the baking powder – hard, solid, no air pockets. Unfortunately many soils are like this. If your soil is like this, it will be necessary to break it up initially so that air can penetrate, plant roots can move freely, and excess water can drain away.

The best tool is a fine tyned garden fork. If your soil is solid and compacted you will unfortunately need to bash it about fairly vigorously the first time. As its structure improves with 500 use and the addition of compost or organic matter, you need to be progressively more and more gentle. If your soil is well structured already, cultivation can be kept to a minimum, and a much more gentle touch is required with the fork. Sometimes you can just gently turn a piece of soil over and it will break up enough – any more vigour can easily destroy the delicate structure. Sense into it and work with care!

Continued over page

Some people feel that inversion is bad, damaging biological activity by burying the top active layer deeper down. This may be true for soils that have been too heavily mulched, where all the activity is confined to the surface mulch and where air penetration into the soil is hampered, resulting in poor structure and less activity underneath. But in a healthy, well structured soil, aeration and biological activity go well down, and inverting the top layer does no harm whatsoever only aiding soil fertility and structure. The best way to incorporate compost into the soil is to spread it on the surface and turn it under with a fork.

Benefits of Hoeing

"Shallow working the soil surface – not deeper than three centimetres breaks up the hard crust and air can enter the soil, allowing it to breathe and encouraging the transformation of substance. Oxygen in the soil enables the micro-organisms to breakdown organic matter so that nutrients become available to developing plants. Maria Thus describes atmospheric nitrogen entering the soil after hoeing and being fixed by bacteria, which has a 'light manuring effect'.

"Each hoeing action has an effect on the interplay between the soil and the atmosphere above, creating chaos in which cosmic forces can become active. We use this knowledge to directly influence crop growth. The biodynamic planting calendar gives specific times, widely known as root, leaf, flower and fruit days, for hoeing particular crops, during which favourable cosmic influences stimulate the part of the plant we want to benefit from later – the root of the carrot and the leaf of the lettuce, for example, or the blossoms of the rose. These favourable times occur approximately every nine days.

"Hoeing also significantly reduces water evaporation from the ground. The capillary tubes which form as the soil settles, bringing moisture to the surface, are broken up. Regular hoeing creates a so-called dust mulch, a shallow, loose, dry soil cover which protects the underlying soil in a similar way a regular mulch material does."

The Star and Farrow, BD Association, U.K., Summer 2005,
The Art of Hoeing, Claudia Weis

Cultivating the Soil

By Terry Forman

Cultivating the soil is a process of applying force to it. Whether it be done by a garden fork, spade plough or harrow it is still the same process. But we use a different implement depending on just what effect we wish to achieve.

Every soil has a certain organised arrangement of its various constituents. The degree of organisation and the types and relative amounts of the constituents, give that soil its particular structure. If we were to compare the soil to a brick wall we could say that the peds in the soil are like the bricks in the wall, and the humus/clay colloids which bind the peds together. The bonding between the peds is not as strong as that within the peds, because within the peds the larger sand and silt particles act like rock aggregate does in concrete, conferring greater strength.

Continued over page

When we apply a force to the soil it radiates out through the weaker parts, that is into all the joints between the peds. The soil then changes from being massive to being friable, i.e. we can now shape it and work it with less force. The joints between the peds are also the places where the water, air, root hairs and micro-organisms will move. These things are of course within the peds also but their movement is far more restricted. What is within the peds, the soil is holding as insurance against difficult times.

If we were to apply a steady force to a brick wall it will usually give way at the mortar joints – unless there is not enough lime in the mortar and it is too hard. However if we just smash at it many of the bricks will also break and the resulting rubble will not be much use for anything except fill. Similarly if we cut the wall into slabs, with a masonry saw, we are left with big heavy pieces of wall that would be very difficult to put together again and any resulting wall would have much less strength.

Cultivating or smashing a brick wall is like cultivating a soil when it is too wet or too dry respectively. The soil would not come apart in a way that allows it to be readily rebuilt. It would finish up as either hard heavy clods (cultivating too wet) or dust (cultivating too dry).

By carefully taking apart a brick wall, the bricks can be used over and over. By carefully cultivating a soil, the peds can be used over and over and the insurance kept in place. Each time the humus/clay binding material on the surface of the peds is exposed then the soil's fertility is able to be harvested. It is the humus/clay colloid which is the storehouse for the nutrients and the water in the soil, and it is the proper working of the limestone principle in the soil that allows this humus/clay colloid to be formed and to be able to constantly renew itself. It represents the life of the soil and all of the activity of micro-organisms, plant roots, worms and so on, leads towards this as a kind of dark flowering within the earth.

So, cultivating, if done correctly, in its successive stages, with the correct implements and always trying to keep the peds intact, is a means of using physical force to direct the harvesting and re-growing of fertility in a way that supports human life and the life of the soil.

Obviously there are some soils, which by their nature should only be cultivated very lightly, if at all and some which can be regularly cultivated. We can also see that the addition of manures and composts, the use of green manures and pasture phases in rotations, must be used to compensate for the cultivation and to give the soil the extra life it will need for rebuilding. If we just add nutrients in chemical form, the peds themselves will soon start to break apart and the insurance will begin to be used up.

It is not difficult to imagine that when you are applying the '500' to the soil, whether onto cultivation or pasture ground, its living forces radiate out through the soil in a similar way and along the same pathways that the physical forces do when we use fork or plough, and that the two can work together hand in hand. When we are using the '500' I think we are really using a very new form of cultivation. We are actually cultivating with life itself and this is why we see the improvement in the feel and the structure of the soil that we do.

Newsleaf, No. 34, Cultivating the Soil, Terry Forman, Pgs 6 & 7

Biodynamic Soil Cultivation

The following article on soil cultivation is applicable to both farming and gardening situations, although the type of implements used will differ.

"Considering all the pros and cons, we may find the truth and the proper practice by investigating the question: why and when does plowing do harm? In olden times a kind of 'plow' was used with no damage to the soil at all. Soils treated with this 'plow' maintained their fertility for thousands of years, as was the case in Egypt, where in fact, this 'plow' is still in use on old-fashioned farms today. It is a wedge-shaped, primitive instrument which does not turn the soil but only breaks the crust and hardpan (if there is one), and stirs up the soil. Trouble started only when this plow was replaced by the iron or steel implement with the moldboard, eg with the invention of the plow which 'turns' the soil. But even the turning plow can be handled in a comparatively harmless way. The problem became serious only when farmers forgot that plowing is an 'art', that there are definite and limited conditions under which soil should be plowed at all. The tractor too, became a tempter to wrong practices with its great power reserve which allows a very deep plowing.

"Harm is done to the soil when the live layer on the surface is turned under to a depth where no life is possible and when the subsoil and dead lower layers are brought to the surface where they require years before the microbe and earthworm life can restore proper humus. The humus turned under will bring about an acid decomposition, forming a solid dead layer, eventually like a kind of peat moss. This all hinders the root development of cultivated plants. The improper plowing of too wet a soil gradually forms a hardpan impenetrable by air, water or roots, thus increasing the acidity etc. Also it may turn up big lumps which will lie in the ground for years.

"The live layer of the soil is at best from four centimeters down to about ten to fifteen centimeters in a well-aerated soil. The material within this layer is interchangeable without loss or destruction of the life. A disking of this layer is good; also turning within the layer will do no harm. In other words, as long as the plow remains within the live layer and is otherwise handled according to right moisture conditions, not too wet and not too dry, avoiding hardpan, lumps or crust, it will do no harm."

"This proper handling of the plow according to the life conditions and structure of the soil is the 'art of plowing'. Farmers possessing this art do no harm to the soil, according to the observation of the writer. Their soil crumbles nicely, does not form a hardpan, in some instances the fields look as if harrowed rather than plowed. The problem is that for many plowmen this is a lost art. We need to learn how to do the right thing at the proper time and place, even how to handle the plow without doing damage."

"Ploughing: Never plough a soil when it is too wet. When the clay sticks to the plough share and the bottom of the furrow gets that slick, glossy look, beware, the result will be lumps and hardpan.

"Never plough into the subsoil. Don't plough too deep. Only as much soil as will fall apart easily as it dries on the surface without lumping or caking should be ploughed or turned. The heavier and the more moist a soil, the less deep you should plough.
I believe in well maintained organic soils ploughing can be reduced to a minimum."

Pfeiffer, E., *Biodynamic Farming and Gardening,* Mercury Press, USA, Vol 1, 2, & 3, 1983

Soils and Cultivation

by Sandra Norman

"When doing any sort of cultivation, at any stage of growing plants, we need to be conscious of the structure and the soil life and use implements and methods that do not destroy the critical components of the soil.

"Throughout this series of articles on the soil, cultivation has been mentioned frequently. So what exactly do we mean by cultivation? The general understanding of the word 'cultivation', in terms of the soil, is the preparation of the soil for gardening or growing crops with some form of cultivation implement. However, this is in fact the tillage of the soil. The terms tillage and cultivation are often used synonymously. However, cultivation encompasses a much broader concept than simply tillage. It includes the initial soil preparation, including tillage, inputs of fertilizers, compost etc, planting, weeding, right through to the time of harvesting.

"Why do we till/cultivate the soil and what are our aims? Our aim always is to have a well-structured soil with a variety of aggregates, including both size and shape, and a variety of pore spaces for air and water. A well-structured soil will allow water to infiltrate, drain readily whilst at the same time holding enough water for both the plants and the soil micro life, as well as providing a medium that allows seeds to germinate and roots to penetrate easily. Whenever we cultivate the soil, we need to be very mindful that we do not damage the structure or destroy the soil microorganisms.

"More specifically, we cultivate the soil for a variety of reasons as follows:

Soil Preparation

"Before we begin to plant anything, the soil needs to be suitably prepared. The initial task is the cultivation/tillage of the ground with some sort of implement. The choice of this implement is very important, as some implements can be very damaging to the soil structure. A tined implement is generally more suitable as it will not turn the soil over too much. The soil micro life is usually in the top 10/15cm and if we turn this top part of the soil under and bury it, the soil life is severely affected. Minimum cultivation is becoming increasingly popular. Our Australian soils are very fragile and the traditional European cultivation practices adopted by the early settlers are now seen as not being suitable for our soils. There are however, many instances when deep cultivation is necessary. For example, if the soil is severely compacted then deep ripping is often necessary. If something like a single tine ripper is used, the soil is broken up deep down without turning the topsoil under. This creates spaces for air and water and loosens the soil generally for the roots to penetrate. A broadfork will also do the same thing for smaller areas.

"Soil preparation also includes adding organic matter, rock dusts, compost etc to the soil. The digging in or slashing of green manure crops is also done at this stage, adding valuable organic matter, which builds up the soil organisms and the fertility of the soil. This should all be done well in advance of anticipated planting time to enable the soil microorganisms to do their work, decomposing and building up the soil fertility.

Weed Control

"The removal of unwanted plants (weeds) can be achieved with cultivation. They can be removed completely (usually some handwork is necessary to do this) or they can be disturbed and left to lie on the surface of the soil. Small annual weeds can be cut just below the soil surface and also left on the surface. This works particularly well on a hot dry day. Disturbing the soil also enables the seed bank in the soil to spring into life and germinate, so follow-up cultivation will be necessary. This is a good way of preparing a weed free bed.

Aeration and Soil Moisture

"When we cultivate the soil with a suitable implement, we are creating spaces for both air and water, both essential for plant roots and other soil organisms. Soil that is left bare with no mulch or plant cover is at risk of having an impenetrable crust form on the top when it rains. This crust stops the oxygen from the atmosphere entering the soil, severely affecting both the plants and the soil organisms. This crust needs to be disturbed.

"Do not cultivate the soil if it is either too dry or too wet. If too dry, then when the soil is cultivated, the soil particles can be shattered and it can turn to 'talcum powder', losing its structure. At the other end of the soil moisture spectrum, if too wet the structure can also be destroyed by creating large clods as well as compacting the soil by walking or driving machinery on the soil. A compacted soil has very few (if any) pore spaces for either air or water and the fine feeder roots of plants have great difficulty penetrating such a soil. The soil needs to have some moisture but not too much. Experience is the best guide.

Pest Control

"Cultivating is a useful tool for pest control. Some of the soil-dwelling pests will be exposed to predators such as birds etc, whilst others will dehydrate when they are exposed to drying conditions. he life cycles of some pests can also be broken if their food source is disturbed or removed.

Implements

"There are many cultivating/tillage implements available. The size and type depends on the size of the area to be cultivated. Hand tools include:

- Mattocks and picks – can be used to break up heavily compacted soils, loosen soil and cut through roots
- Shovels – available with long or short handles (the long handle is better for the back assuming it is used correctly). Shovels invert the soil, turning under weeds or organic matter but can leave large clods
- Spades – useful for edging garden beds, digging trenches, moving soil and other materials
- Garden forks – these tined implements are very useful for breaking up, loosening and aerating the soil as well as mixing in compost etc. These tined implements are much 'kinder' to the soil organisms. Tined implements are the recommended choice for biodynamic gardeners and farmers
- Garden rakes – used for breaking up the soil, leveling and creating a fine tilth. The tines break up the soil and the smooth metal bar levels the surface – a very useful tool
- Hoes – there are various designs but they all are used to break up the surface crust and for weed control
- Broadfork – very useful for loosening and aerating soil, particularly compacted soil.

Continued over page

"There is a range of tractor drawn implements that do the same functions as the hand tools.

"Initial soil preparation is always time and money well spent because the plants in a well prepared soil will have the best chance available to grow to their full potential, assuming adequate water is available and the soil is balanced. Continued cultivation throughout the life of the plant is also necessary.

"Plants grown in a properly prepared, well-structured and balanced soil will be healthy. A well-tended garden or farm is evident even to the inexperienced casual observer.

"When doing any sort of cultivation (including tillage) at any stage of growing plants, we need to be conscious of the structure and the soil life and use implements and methods that do not destroy either of these critical components of the soil."

Hunter Organics, Summer 2004 pp 14 & 15

Soil Cultivation

"Poorly managed tillage can cause these problems, as well as fossil fuel and harm crop growth. Mistakes include using the worn tool or using the right tool at the right time, too often, in the wrong way, in the wrong place or at an improper orientation to field slope.

"You make the difference by selecting the right tool and using it wisely. Occasional tillage – even moldboard plowing dome properly – can actually decrease erosion by increasing moisture infiltration rates.

"Cover crops, compost, manure and other organic matter incorporated into biologically active soil bring measurable changes. Properly managed, additional organic matter can increase infiltration and water-holding capacity, thereby reducing erosion potential.

"A cultivation pass before a rain shower will have less impact where the soil has greater tilth and soaks up more rain. The same tool used the same way across the road on 'tighter' soil will create channels and probably lead to more erosive water movement.

"A controlled traffic field plan (running equipment wheels in the same row middles season to season), using deep-rooted rotation crops and staying out of the field in wet conditions help to minimise compaction."

Bowman. G, *Steel in the Field, A Farmer's Guide to Weed Management Tools*, Sustainable Agricultural Network, 1997.

Reduced Cultivation

Reduced cultivation is another method of maintaining the fertility of the soil. Traditionally soils were ploughed to:

1. control weeds
2. conserve moisture
3. prepare a suitable seedbed.

However ploughing compacted soils destroyed soil structure, reduced organic matter levels and increased the risk of soil erosion.

Direct drilling is a new method where the seed is drilled directly into unploughed land and weeds are controlled by alternative methods.

Advantages of reduced cultivation include:

- improved soil structure e.g. less compaction, increased porosity, infiltration and water storage
- less risk of erosion
- increased soil organic matter content
- reduced fuel and machinery costs.

Requirements for Biodynamic Soil Cultivations

- implements and techniques must maintain and improve soil structure
- cultivating should not be carried out during adverse weather conditions
- cultivating only at the right soil conditions, when soils are neither too wet or too dry
- cultivating should not be too deep, only to the depth of the top soil
- cultivating should not mix top soil and sub soil. The heavier and the more moist a soil, the less deep you should plough.
- the right cultivating equipment should be chosen to suit the purpose. In gardening situations soil cultivation is always done with a fork, avoid use of spades or shovels which can create vertical hardpans. When using machinery aim to achieve the same outcome as when cultivations are done by hand
- avoid use of heavy machinery
- avoid compaction and erosion of the top soil
- cultivation must be carried out at the right speed, preferable the slowest possible speed, no faster than a cow or horse would walk
- paddocks should be grazed or slashed before ploughing
- when using equipment avoid implements which cut the soil
- soils should be slowly turned and broken apart
- leave reasonably sized lumps when cultivating, avoid pulverising the soil
- ploughing should ideally not create any dust
- layer of soil just below cultivation depth should be loosened, not smeared or scratched
- cultivation should crack the soil upwards and sideways
- there should be no smearing of the sides, no smooth ridges
- soil cultivating must not create any hardpans
- the depth of soil cultivation can be increased as the soil improves
- in hilly country cultivation must be carried out along the contour.

Methods to Cultivate the Soil

Types of Soil Cultivation
Depending on the aim of the soil cultivation, different cultivation practices are implemented during different stages of the cropping cycle; after harvesting, before sowing or planting or while the crop stands.

Post-Harvest
In order to accelerate decomposition, the residues of the previous crop are incorporated into the soil before preparing the seedbed for the next crop. Crop residues and green manure crops should be worked only into the topsoil layer (15 to 20cm), as decomposition in deeper soil layers is incomplete, producing growth inhibiting substances which can harm the next crop.

Primary Tillage
In annual crops or new plantations, primary tillage is usually done with a plough or a similar instrument. As a principle, soil cultivation should achieve a flat turning of the top soil and a loosening of the medium deep soil. Deep turning soil cultivation mixes the soil layers, harms soil organisms and disturbs the natural structure of the soil.

Seedbed Preparation
Before sowing or planting, secondary soil cultivation is done to crush and smoothen the ploughed surface. Seedbed preparation has the purpose to provide enough loose soil of appropriate clod sizes. If weed pressure is high, seedbeds can be prepared early thus allowing weed seeds to germinate before the crop is sown. Shallow soil cultivation after some days is sufficient to eliminate the young weed seedlings. Where water logging is a problem, seedbeds can be established as mounds or ridges.

In-Between the Crop
Once the crop is established, shallow soil cultivation e.g. by hoeing helps to suppress weeds. It also enhances the aeration of the soil and at the same time reduces the evaporation of soil moisture from the deeper soil layers. When crops are temporarily lacking nutrients, shallow soil cultivation can stimulate the decomposition of organic matter thus making nutrients available.

IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

Appropriate Tools for Soil Cultivation

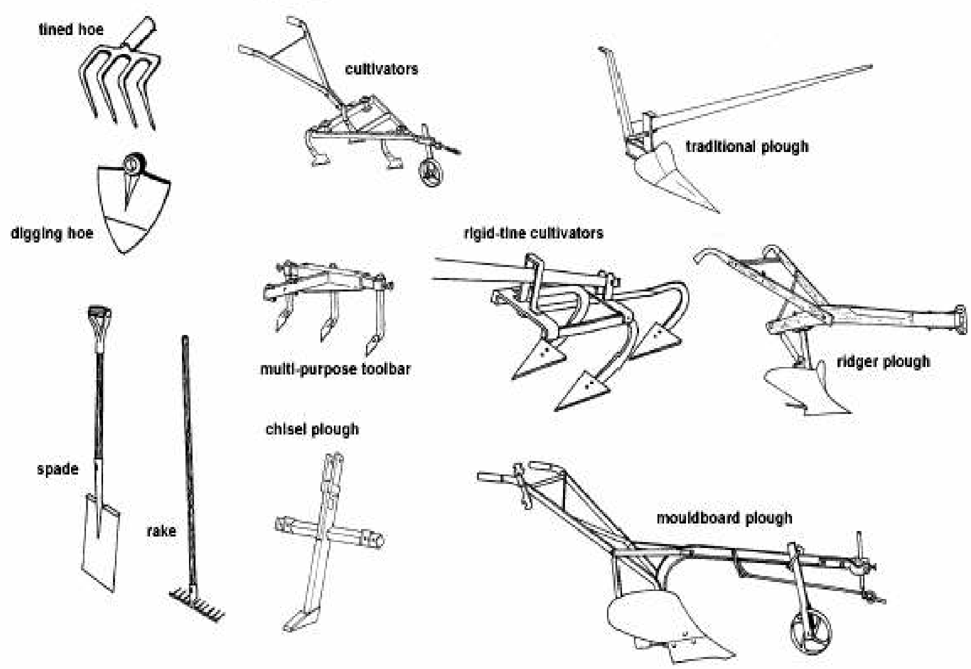
The tools for soil cultivation can be grouped in four types:

- Tools for primary cultivation; pole plough, mould board plough, digging fork, spade
- Tools for secondary cultivation; cultivators, harrows, rakes
- Tools for inter-row cultivation; inter-row cultivators, hoes
- Tools for land forming; ridgers, hoes

Tools should be chosen considering the soil cultivation purpose, the soil type, the crop and the available power source. Therefore, it is difficult to make general recommendations.

IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

Appropriate tools for soil cultivation



(Source: „Tools for Agriculture", CTA & GRET)

IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

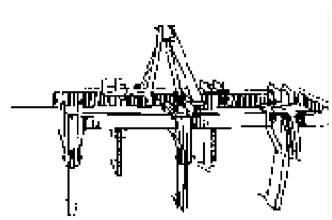
Soil Cultivation Equipment

The principle of cultivation is to turn and break down the soil to a fine tilth to provide the ideal environment for seeds to germinate. This system has been used for centuries in Europe where topsoils are deep, rainfall is high and, because of cooler temperatures, organic matter takes much longer to break down. In Australia, regular intensive cultivation by this system has degraded the soil structure. Our soils are much older, our climate is hotter and drier, and organic matter breaks down quickly.

Knowing how different cultivation implements affect soil can help you protect and conserve the soil on your farm.

Cultivation Implements

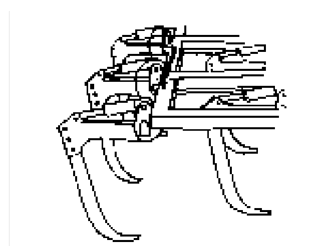
Ripper (subsoiler)



Rippers or subsoilers break up compacted soil below the depth reached by conventional cultivation, to improve drainage and aeration. There are several types of deep rippers: vertical, agroplow, parabolic, C shank (SJ) and paraplow, and they can reach 30–90 cm into the soil. Most have slanted tines or a sharply angled leading point to lessen the power required to pull the ripper. This design also helps lift and shatter the subsoil so that any compacted layer is broken up.

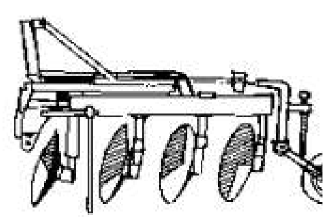
Soil should be reasonably dry when it is ripped. Ripping wet soil does not shatter the subsoil and can smear and seal the soil beside the ripper tine. Smeared surfaces prevent air, water and roots moving through the soil.

Chisel Plough



Chisel ploughs are used to shatter but not turn or move the soil. They work on the same principle as rippers, but in the top 30 cm of the soil. Again, the soil must be dry to moist, otherwise the plough will smear and seal the soil surfaces.

Disc Ploughs and Offset Discs

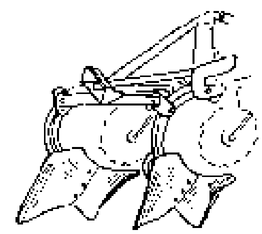


Disc ploughs break up undisturbed soil by inverting it to bury surface weeds and trash. Regular use of disc ploughs reduces soil aggregates to small particles and produces a compacted layer or plough pan which prevents air, water or roots penetrating the subsoil.

When it rains, soil particles on the surface collapse together to form a crust which repels air and water and is difficult for seedlings to break through. Offset disc ploughs, which have two rows of discs running at angles to each other, serve a similar purpose. They are usually used as a second tillage implement, and for initial tillage on lighter soils.

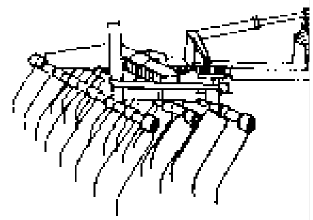
Mouldboard Plough

The oblong-shaped mouldboard plough is shaped to cut and turn over soil to bury surface residue. It is rarely used in Australia's shallow topsoils as it brings up less fertile subsoil. However, it has been used successfully where hard setting or crusting occurs to bring up swelling or shrinking clay subsoil to improve topsoil structure.



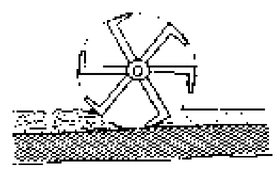
Harrows

Harrows are used for seedbed preparation and light surface cultivation to remove weeds after seeding. If used regularly they will break down and pulverise the soil structure.



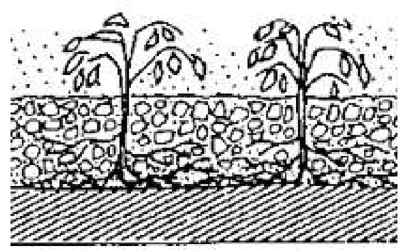
Rotary Hoe

Rotary hoes aerate the soil and provide a fine seedbed. However, in the process, the rotating shoes compact the soil underneath the level they are aerating, and destroy the soil structure by pulverising the seedbed, leading to crusting and compaction when the soil is wet.



Plough Pans

Plough pans are caused by the smearing action of disc ploughs continually operating at the same depth over a long period. It is difficult for plant roots, water or air to move through this pan, so plant performance is affected. The use of heavy machinery on wet soil also compacts soil over time, creating a hard layer similar to a plough pan.



Because cultivation can degrade the structure of the soil, there is an increasing trend to minimum cultivation and even no cultivation, where seed is direct drilled into undisturbed soil.

Minimum Cultivation

Minimum cultivation refers to a reduction in the number of times the paddock is cultivated for crop production. On lighter soils it is often possible to plough and seed soil in one operation. This is more difficult on the heavier clay soils where roots cannot move through the soil as easily.

Direct Drill

Direct drill relies on herbicides to keep competing weeds down, and organic matter to maintain soil structure and make it easy for germinating seeds to move through the soil. Retaining organic matter on the soil surface also reduces erosion and conserves soil moisture.

Sourced from: NSW Department of Primary Industries,
http://www.dpi.nsw.gov.au/agriculture/resources/soils/structure/cultivation

Deep Ripping

By Phil Barnett

The site can be ripped well into the subsoil layers to a depth of 60cm or deeper if possible. This should be combined with the lime or gypsum application to increase the effectiveness of the operation. (*Authors note; deep ripping should only be undertaken to the depth of existing plant roots. Deep ripping to this depth encourages rapid plant root growth into the spaces provided by the deep ripping, thus avoiding the necessity to use lime or gypsum to hold open the spaces created in the soil.)* Make several passes along the planting line to a width of 2 to 3 metres. Rip down the slope for best drainage.

The purpose of deep ripping is to create a continuous system of soil pores from the surface to the lower depths to allow water infiltration, gas exchange, and drainage. Ripping will also reduce soil strength and facilitate root extension. To be successful the soil should crumble and the majority of soil particles in the ripped subsoil should be less than 20mm in size. This can only be achieved if the soil conditions are right at the time of ripping, and the operation is carried out in the correct way:

The water content of the clay at ripping is critical and should be drier than field capacity but above the wilting point water content. Usually these conditions will be found in late spring or late autumn.

To gauge the correct moisture content, mould some clay in your hand till you form a ball—then break it open and take a pinch of soil from the centre and then roll this into a thread. If you can't roll a thread, the soil is too dry, if it crumbles before it reaches 3mm in diameter it is ideal, but if it rolls thinner than 3mm it is too wet.
The soil should break down to a friable mass and crumble up—not just smear or deform.
The ripping rate must be low—less than 5km/h.

Avoid tractor wheel or track slip as this will damage the surface soil. The job may require several passes at gradually increasing depth to achieve the desired result. It is essential that the ripping process brings the minimum amount of subsoil to the surface because this will reduce the free draining nature of the topsoil.

With a clay subsoil use a ripper with a rake angle 20 degrees from horizontal and wings attached to the tine having a sweep angle of 90 degrees and a width of 0.7 of the working depth. During ripping, check on the effectiveness of the operation by digging a trench behind the ripper and look at the soil profile to see if:

- there is enough lateral fracturing and loosening,
- there is no compaction,
- and the clods are less than 20mm diameter.

After ripping be careful to avoid any re-compaction by keeping all vehicles off the rip lines, including the tractor. Don't track roll to level the ground, instead drag a heavy bar over the rip line to smooth it off.

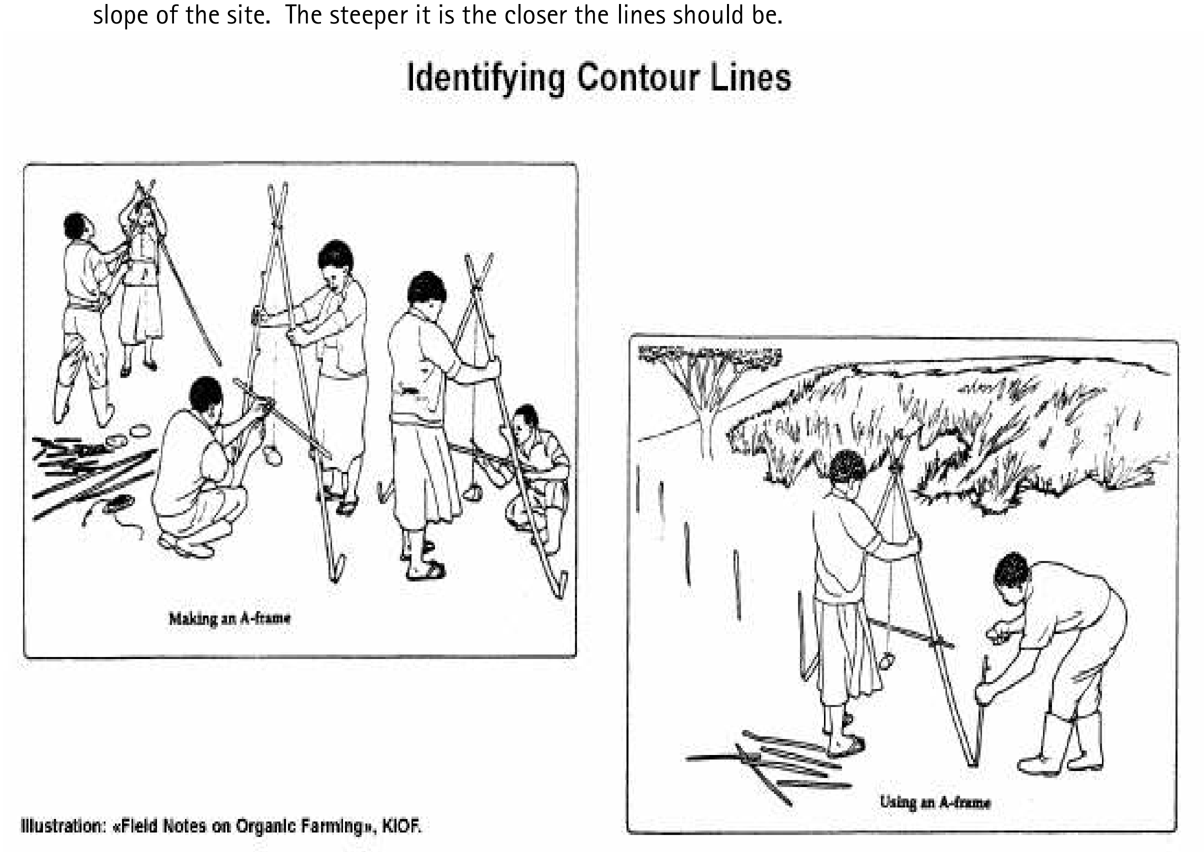
Extra notes: Deep ripping should be carried out when the soil is just moist, so that widespread cracking will occur. Check by digging how far the cracking extends, to determine how close the rip lines should be.

Identifying Contour Lines

A simple way to identify contour lines on a slope is to use the A-frame. The A-frame is a simple tool made from three poles, some rope, a stone and a supply of stakes.

How to build and use an A-frame.

1. Fix three poles of about 25 metres ling each in a position forming an even 'A'. If rope is not sufficient to tie the ends, use nails.
2. Tie one end of a piece of cord to the top of the 'A' and fix a stone tied to the other end so that the stone is at some distance from the ground and the crossbar.
3. Put the A-frame upright and mark the position of both legs. Then, mark the point where the string passes the crossbar of the 'A'.
4. Turn the A-frame so that the placement of the legs is reversed. Again mark the point where the string passes the crossbar. If the two marks are not at the same point, mark a third point with a knife exactly halfway between the first two.
5. Drive the first stake at the edge at the top of the field. Place one leg of the A-frame above and touching the stake. Place the other leg in such a position that the string passes the level position point of the crossbar.
6. Drive another stake into the ground just below the second leg. Move the A-frame and continue in the same way across the field.
7. The next contour line is placed 3 to 6 metres below the first line, depending on the slope of the site. The steeper it is the closer the lines should be.



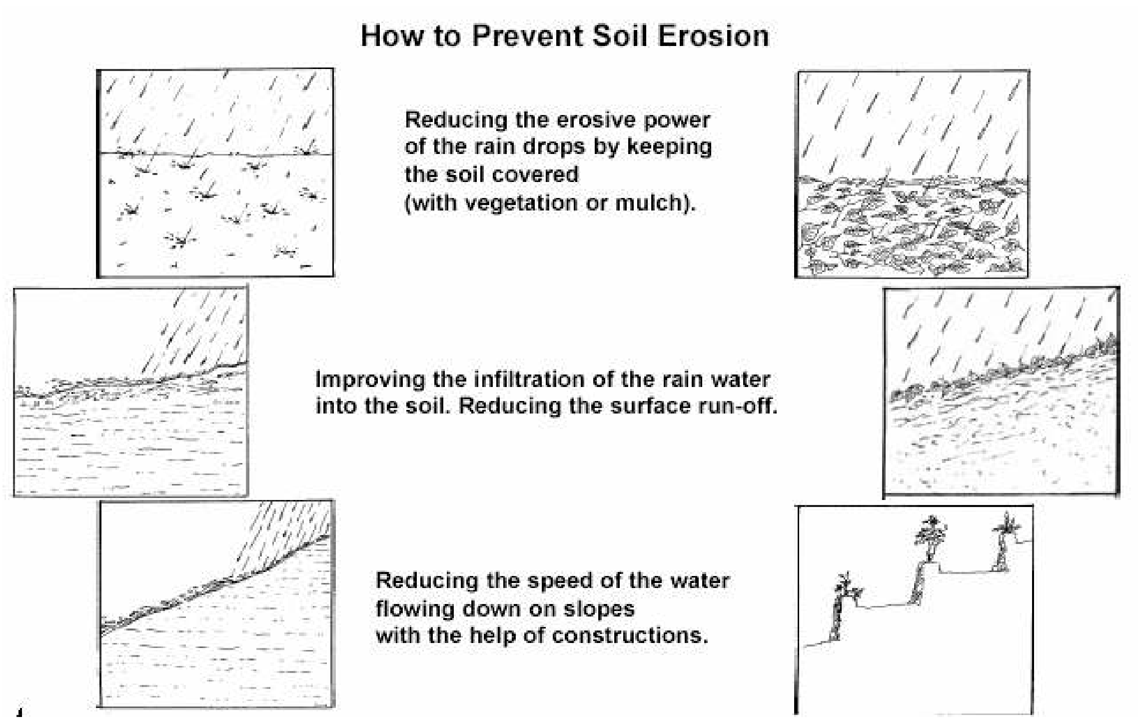
IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

Soil Erosion

Soil erosion is caused by a breakdown in soil structure and loss of organic matter. Overgrazing, chemical use and inappropriate cultivation methods all lead to erosion of the soil. Erosion is a direct consequence of removing the vegetative cover on the soil surface, both the plants and the mulch that is created by the plants.

Signs of Soil Erosion

- Bare earth between plants
- Litter banks where vegetation has been washed down
- Signs of water flow
- Silting of rivers
- Lower ground water levels.



IFOAM Training Manual for Organic Agriculture in the Tropics, 2003,
Complied by FiBL, ISBN 3-934055-25-7

Soil Salinity

The impact of land use on soil structure and condition is a major cause of dryland salinity, according to Robert Gourlay, Business Development Manager of Mitchell Resource Intelligence Pty. Ltd (MRI).

"Objective measurement by MRI over more than a decade shows dryland salinity is due in most part to a decline in soil structure caused by land use practices and subsequent loss or organic matter.

"The decline in soil structure decreases the permeability of the soil, resulting in increased near-surface lateral flow of water and accumulation of water in accession areas. That in turn increases the salinity of the soil by increasing its contact with the soil. These effects are magnified by reduced water use by vegetation, increasing the amount of water in the system, and decreased drainage from accession areas due to salt (NaCl) decreasing soil permeability. The additional water causes waterlogging, not salinisation, in systems containing little salt.

"From a process viewpoint, dryland salinity is a symptom of land degradation rather than the cause. We believe dryland salinity is caused by a change in the pattern of water drainage through soils, which can occur without an increase in the amount of drainage of water. A decrease in the water use by vegetation can enhance the development of dryland salinity but it is not the cause. And contrary to current wisdom, loss of grasses may be more significant than trees in triggering dryland salinisation.

"Trees produce large root channels that provide considerable benefit but grasses tend to build higher levels of soil organic matter than trees. While the relative benefit of trees and grasses is uncertain, tree killing promotes grass growth that can compensate for the loss of trees provided the grasses are not heavily grazed.

"The main land management practices that cause adverse dryland salinity are grazing and cultivation rather than tree removal. Salt accumulates in naturally in soils where there is limited percolation of water through the soil, with the depth of accumulation depending on soil properties, rainfall and vegetation chacteristics.

"Decreasing the permeability of the soil and/or the depth of extraction by plants results in salt moving closer to the surface. Patterns of water movement through soils are determined largely by the water potential gradient - determined by factors such as soil moisture, salinity and elevation - and resistance to flow. Flow resistance is primarily determined by soil structure, with coarse sands being highly permeable, and heavy clays highly impermeable. However, clays develop cracks and root channels form with the death and decay of plant roots, providing pathways for water through otherwise largely impermeable layers.

"Other factors affecting the movement of saline water within the landscape include geological fault lines, paleo-drainage systems and changes in vegetation. The occurrence of preferred pathways through the soil strongly influences patterns of water movement and salt distribution, Dr Tunstall said.

Continued over page

"Water moves rapidly down cracks and old root channels. Water percolating in undisturbed systems tends to have much lower salinity than water in the bulk of the soil because it drains rapidly through preferred drainage channels, essentially coming into minimal contact with the bulk of the soil. By comparison, the salinity of water percolating through structurally degraded soil tends to match that in the soil.

Percolation of water through the soil is required to reduce soil salinity and to promote the movement of salt required to cause dryland salinity.

"However, percolating water may not remove salt because clays can absorb salt from the water. However, there is now clear evidence that the use of water conditioners on irrigation systems will significantly improve soil structure, salt percolation and plant health. And while water flowing through soil increases in salinity because of the uptake of essentially pure water by plants, the salinity of the water flowing through the soil via cracks and old root channels tends to be less than the salt concentration in the bulk of the soil because it does not come into contact with the bulk of the soil. Diffusion of salt from the bulk of the soil to drainage channels is slow, so water flowing through channels can have low salinity compared to the salinity of the surrounding soil.

"Loss of preferred soil pathways, as occurs with soil structural decline, increases salinisation because without preferred pathways the percolating water comes into closer contact with the bulk of the soil and spends more time in the soil, resulting in the salinity of the water tending to come into balance with that in the bulk of the soil.

"Soil structural decline tends to increase the salinity of percolating water." The structural aspects of systems that affect water movement can be addressed at various scales, Dr Tunstall said.

"At a local scale the soil structure dominates, with factors such as texture profiles, organic matter, cracks, and root channels affecting the response. On a larger scale landscape effects become prominent, with terrain and layering of soil profiles affecting the outcome, and geological features such as differences in materials, and structures such as lineaments, fault lines, paleo-drainage and dykes also come into play.

"There are no adverse effects on land where water simple drains from the system, as occurs with drainage into rivers. Water can take several paths from high to low points in the landscape, with the relative flows along different paths determined by the resistances in each pathway. Resistance to flow is least on the soil surface and run-off generally accounts for most lateral flow of water."

Acres Australia, The National Newspaper of Sustainable Agriculture, Australia, Volume 11, Number 2, Page 7, October 2003

Soil Salinity

- Farm management practices are directly related to the extent, duration and severity of dryland salinity.
- Farm management practices which increase soil biota (raised organic carbon levels) stores additional water in the humus for plant production and reduces recharge to the groundwater.
- Farm management practices which increase soil biota also promote soil structure and increased soil porosity, which in-turn enables salt leaching and the commencement of soil profile respiration.
- The remediation of damaged saline landscapes is a most delicate process commencing at the microscopic level and is possible only if the capillary fringe is inhibited, through one means or another, from being present at the surface of the soil.
- Engineering solutions such as subsurface drainage lowers local groundwater and is a way to remove excess recharge to the groundwater and lower the water table in upstream localities, hence lowering the capillary fringe from the soil surface.

Biodynamic Growing, Bio-Dynamic Agriculture Association Australia,
No. 5, December 2005.