PRINCIPLES OF SUSTAINABLE AGRICULTURE

MANAGING SOIL STRUCTURE

Department of Agriculture
and Rural Affairs

National
Soil
Conservation
Program

The year 1990 is the Year of Landcare and the beginning of the Decade of Landcare, with its focus on soil degradation.

As part of this initiative, the Federal government, through the National Soil Conservation Program (NSCP), is supporting this booklet and the associated video, the first in a series outlining the principles of rational and sustainable agriculture.

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PRINCIPLES OF SUSTAINABLE AGRICULTURE

1. MANAGING SOIL STRUCTURE

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MANAGING SOIL STRUCTURE

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FOREWORD

by Hon Barry Rowe, Victorian Minister for Agriculture and Rural Affairs

Soil is the upper weathered layer of the earths crust, in which life exists, and on which life all over the world is dependant. Maintaining this vital resource is of increasing importance as we approach the year 2000 and the earth's population reaches 6 billion.

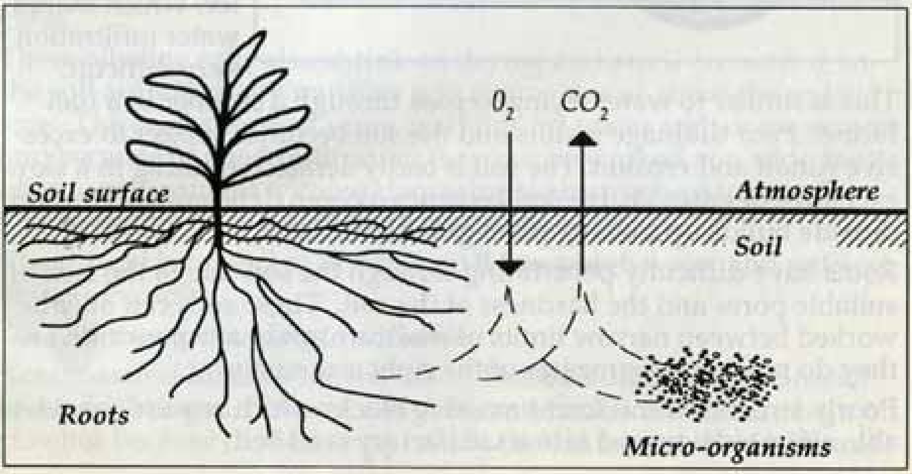
The challenge facing agriculture is to develop farming systems which can improve productivity, while maintaining and improving the resource base of soil and water. This process of sustainable development is particularly applicable to the management of our soils which are ancient and quite fragile. This booklet brings together many of the principles underlying soil science and presents them in a clear and easily comprehensible format, and will assist farmers, advisors and associated industries develop the farming systems needed for the long term prosperity of Australian agriculture.

WHAT IS SOIL STRUCTURE?

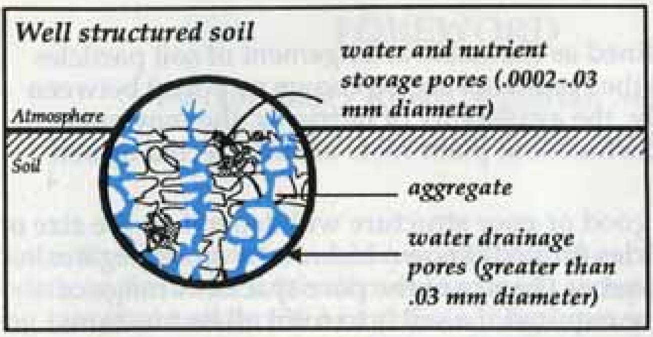
Soil structure is defined as the stable arrangement of soil particles (clay,silt,sand) and the resultant spaces (known as pores) between them. Water supply, the availability of nutrients, the movement of gases and the establishment of plant roots are all affected by soil structure.

Whether a soil has good or poor structure will depend on the size of the clusters of particles formed (known technically as aggregates) which will then influence the size of the pore spaces. A range of stable aggregates are required if a soil is to fulfil all its functions.

Well structured soil has a high proportion of aggregates which are not easily broken down. These aggregates have a diameter of 0.5 - 2 mm or larger (roughly the same size as a pinhead). Because the aggregates do not pack closely together, the soil posesses large pores (greater than 0.03 mm diameter) which allow water to move through the soil rapidly. Such soils can be worked over a wide range of moisture contents, runoff is low and erosion minimal. These pores also allow rapid exchange of gases between the soil and the atmosphere. This is an important process since plant roots and the majority of soil micro-organisms require oxygen (O_2) and at the same time produce carbon dioxide (CO_2). This is shown in the diagram.

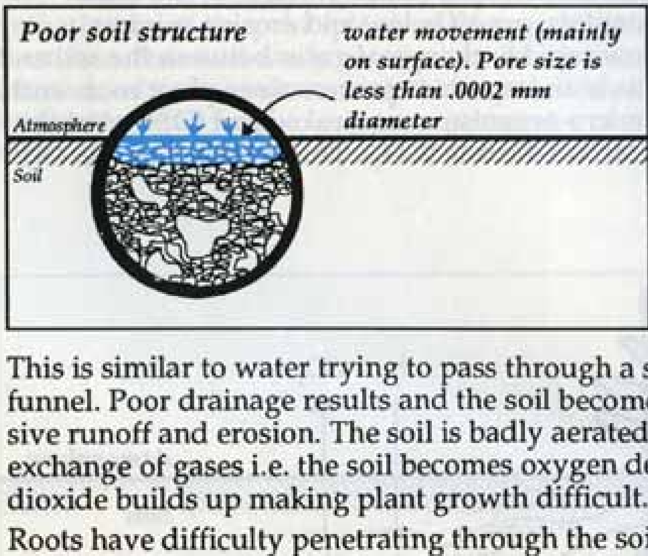


(HILLEL, 1990)



Pores of 0.03 mm and greater also allow roots to easily penetrate through the soil. A well structured soil also contains a high proportion of medium size pores. Pores of this size are important since they contain nearly all water and nutrients extracted by plants.

A poorly structured soil has a high proportion of very small individual particles (less than 0.001 mm diameter; not visible to the naked eye) and few water stable aggregates. Since the soil particles pack closely together, there are very small pores present (less than 0.0002 mm diameter) which makes water infiltration very difficult.



This is similar to water trying to pass through a strainer in a fuel funnel. Poor drainage results and the soil becomes subject to excessive runoff and erosion. The soil is badly aerated resulting in a slow exchange of gases i.e. the soil becomes oxygen deficient and carbon dioxide builds up making plant growth difficult.

Roots have difficulty penetrating through the soil due to the lack of suitable pores and the hardness of the soil. These soils can only be worked between narrow limits of moisture, and have poor tilth i.e. they do not form aggregates of the right size easily.

Poorly structured soil forms massive blocks which require considerable effort to be turned into a satisfactory seed bed.

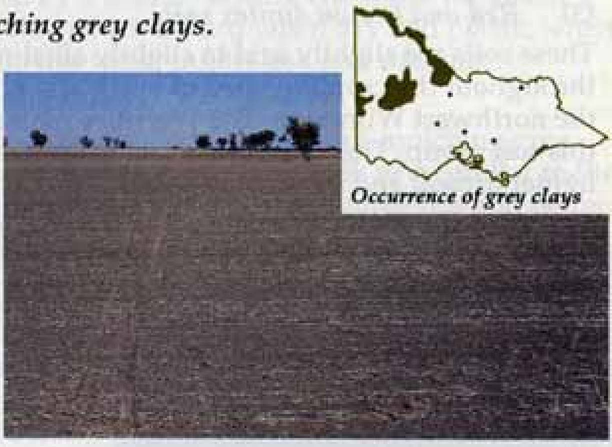
SOIL TYPES AND THEIR STRUCTURE

Many people refer to soil structure in terms of a 'heavy' or 'light' characteristic. This is really a description of the size of particles in the soil and is more correctly called soil texture. Texture analysis is undertaken by rubbing the soil between the fingers. In effect, the soil is crushed in order to "feel" the soil. This is not an interpretation of soil structure since the arrangement of aggregates is destroyed once crushed. Soil structure and soil texture are two different measurements.

Let us consider six common soils in Victoria and what determines their structure.

(1) Wimmera self-mulching grey clays.

The grey clays of the Wimmera have an excellent structure due to their clay content being aggregated by lime naturally present in the soil. It is the calcium in lime which acts as a cementing agent. i.e. it limits dispersion of aggregates.



Occurrence of grey clays

These alkaline soils also shrink on drying and swell on wetting so the soil automatically mulches into aggregates of about the right size. The cracks formed serve as drains for water and air movement and because of good infiltration they can be worked at a wide range of moisture content without damaging their structure too much. Consequently, they are called friable soils.

The topsoil is up to 2 m in depth so it has a high water and nutrient storage capacity.

(2) Krasnozems (potato red soil).

Krasnozem is Russian for red land. These acidic soils are common around Warragul, Ballarat, Kinglake and Healsville and are high in clay but because of their composition (rich in iron and aluminium) they are friable and permeable. Compounds of aluminium and iron cement particles into very stable aggregates so that a high proportion of large pores exist making drainage rapid. This characteristic is well suited to a wet climate although during dry seasons the soil surface may become too dry. The soil can be worked over a wide range of moisture levels with a low risk of crusting and erosion. This soil is characterized by high organic matter due to the interaction of organic material with clay.

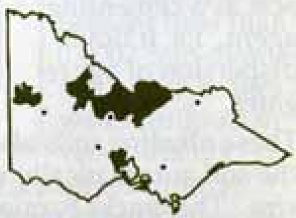
Occurrence of Krasnozems

(3) *Red and brown duplex soils.*

These soils are slightly acid to slightly alkaline and are present throughout the cropping area of north and northeast Victoria and the northwest Wimmera. The Werribee plains are also included in this soil group. They have a distinct texture contrast between the lighter topsoil and heavy clay subsoil.

The soil has a high clay content (20%) and consists of a loamy texture at the surface. Organic matter is the main binding agent contributing to stable aggregates. These soils are, however, often low in organic matter due to cultivation.

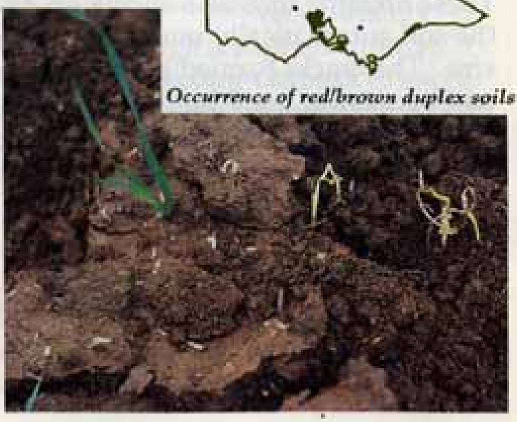
Upon wetting the soil disperses into individual clay particles and forms a "concrete-like" crust. Such soils are called dispersive soils.



Occurrence of red/brown duplex soils

Dispersion results in fewer large-sized pores which makes infiltration and drainage difficult and increases waterlogging and the incidence of runoff and erosion.

The range of moisture content over which these soils can be worked is narrow and the soil becomes pulverised when cultivated dry.



Aggregate formation can be improved by the inclusion of pasture in rotation (this increases the organic matter content).

The lack of medium-sized pores reduces the capacity for water storage. The shallow topsoil (10-20 cm) contributes to this and limits root development. The hardsetting characteristic after rain is a further limiting factor to crop establishment but this can be overcome by gypsum application. Gypsum promotes stable aggregation of the clay particles but is a temporary solution. Stable improvement in structure depends on increasing organic matter bonding.

The soil is characterised by a distinct texture change at the 20 cm depth to a red-brown clay which is hard when dry and plastic when moist. This further impedes water infiltration and drainage.

(4) Self-mulching brown clays.

These alkaline soils are intermingled with the self-mulching grey clays and the red/brown duplex soils. They look very similar to the red/brown duplex soils but have more stable aggregates and better infiltration and drainage.

This is primarily due to their lime content and mulching characteristic. The soil contains higher salt levels than the self-mulching grey clays so aggregates are less friable when moist, stickier when wet and more readily dispersive. The productivity of the brown clays is limited by their lower ability to hold water.

(5) Mallee soils.

These are the Mallee sands (dunes) and the Mallee loams (plains). They are found throughout the Mallee and the northern Wimmera and are alkaline in nature.

The dunes vary from sand to sandy loam. As a result, the surface horizon is highly permeable to water and air and readily allows root penetration. The sand grains stick together very weakly. There is a low water storage capacity and leaching is severe.

The subsoil consists of a compact clayey sand which restricts root development. During wet periods, the topsoil becomes saturated because of the restricted infiltration of water into the subsoil.

Occurrence of Mallee soils

The plains range from sand to clay loam. The soil has a better structure than the dunes because of the clay content. The erosion risk is lower than that of the dunes.

With an increase in clay and calcium content, the capacity of the soil to store water increases. This is further increased by its slightly higher organic matter compared to the dunes. Organic matter keeps aggregates together giving greater soil stability. The soil profile is uniform so it has better permeability than the dunes.

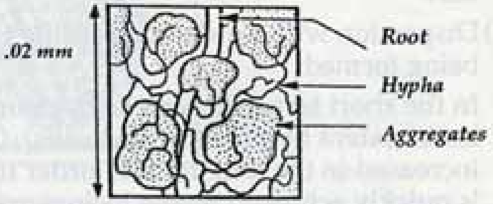
ORGANIC MATTER

As part of the soil descriptions, organic matter was mentioned as a desirable characteristic. This is because organic matter acts like a glue helping to bind soil particles into stable aggregates. As a result, it indirectly influences the soils water holding capacity, air permeability, nutrient availability, infiltration and the activity of soil organisms, all of which affect plant growth.

Organic matter is made up of plant roots, fungal threads (known as hyphae) and complex sugars called polysaccharides.

Fine plant roots and fungal hyphae entangle soil particles so holding them together. This is similar to wrapping a bunch of parcels with string. The combined strength of hyphae and roots ensures that aggregates do not crumble nor collapse when wet. This type of organic matter may persist for months or perhaps years but is quickly broken as a result of cultivation.

Roots and hyphae



TISDALL & OADES (1982)

Roots and hyphae stabilize quite large water stable aggregates up to 2 mm in diameter.

Polysaccharides may be produced by soil micro-organisms or may originate from plant roots and contribute to stabilizing small soil aggregates of 0.02 mm diameter. This size is so small it cannot be seen by the naked eye. These bonds are destroyed rapidly by cultivation which exposes the polysaccharides to micro-organisms hungry for food (for more detail see reference no. 1).

SLAKING AND DISPERSION

Summary

Slaking and dispersion are two processes which will degrade soil structure upon wetting. Slaking occurs within minutes and causes the breakdown of aggregates into smaller sizes. Dispersion, on the other hand, takes hours and causes the breakdown of aggregates into individual clay, silt and sand particles.

Slaking and dispersion may act seperately or in combination, causing the following effects;

(1) Severe slaking with no dispersion resulting in crusting mainly of the surface layers.

This can be overcome by increasing the organic matter content of the soil.

(2) Slaking with dispersion resulting in crusting of the surface soil.

Gypsum and increasing organic matter will overcome this problem.

(3) Dispersion with no slaking leading to a 'concrete-like' lump being formed.

In the short term, this can be overcome by gypsum and to a lesser extent by lime (on acid soils). Organic matter needs to be increased in the long term in order to maintain soil stability. This is quickly achieved by the inclusion of a pasture phase in rotation.

The three processes are illustrated in the diagram opposite.

Slaking

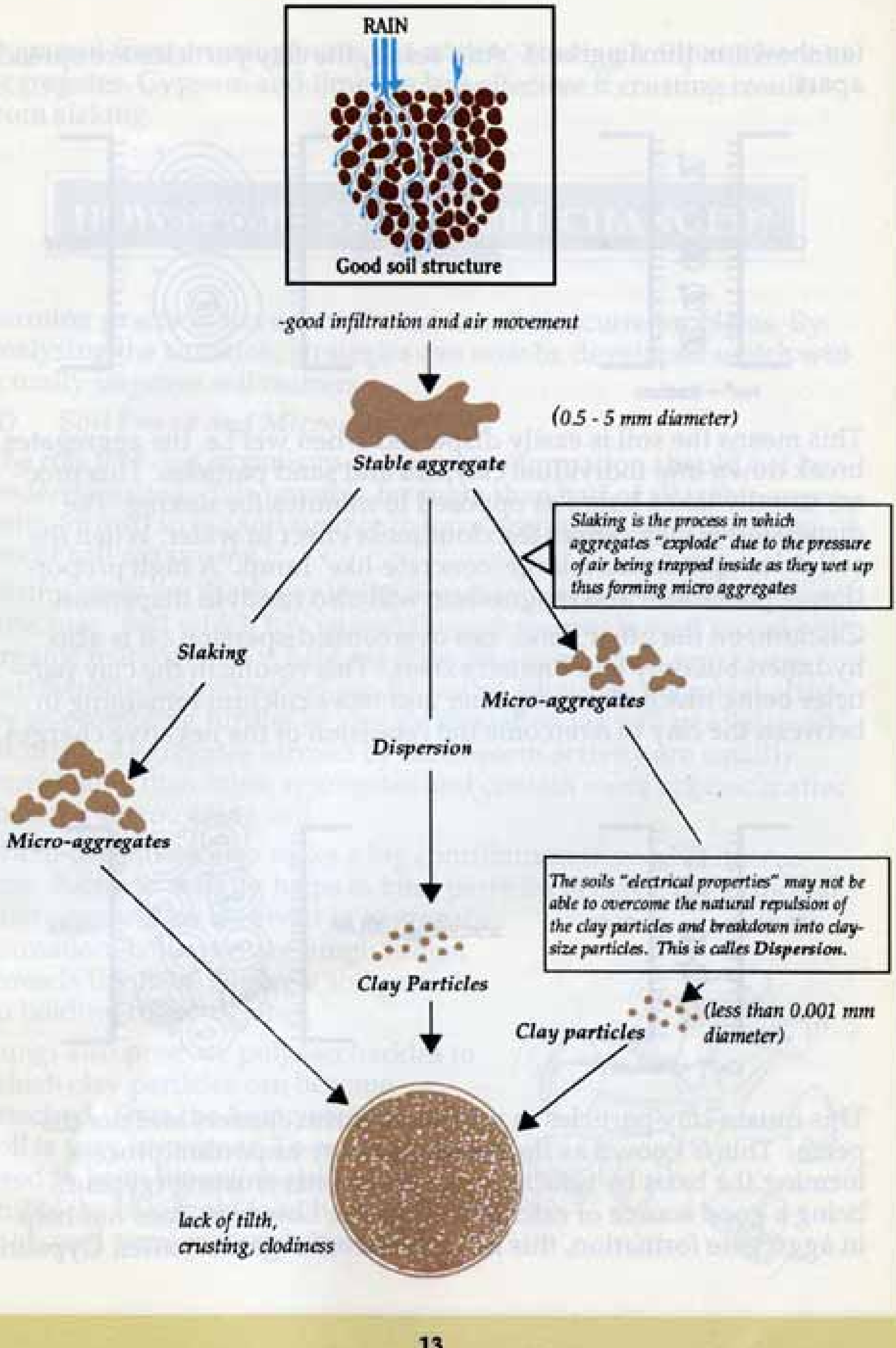
Once wet, aggregates swell and it is inevitable that fragments of soil will break off. This process, however, is aggravated by the air being forced out of the aggregate by the ingoing water. In essence, the air is pushed out faster than it can move out, resulting in the build up of pressure and the "explosion" of the aggregate. This is called slaking. Severe slaking will limit water infiltration and seedling emergence. Slaking is minimal during constant, gentle rain but a sudden downpour or flood irrigation will aggravate it. Slaking is severe in soils with low organic matter and with frequent cultivation. Stubble retained on the surface can help to lessen the impact of slaking.

Dispersion

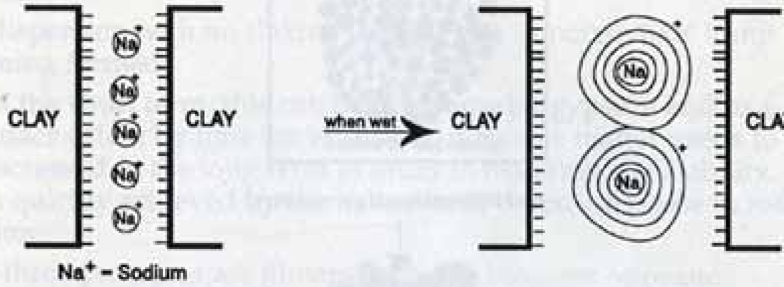
Stable aggregate formation is also influenced by soil 'electrical' properties. Clay particles on their own carry a nett negative charge and so tend to repel each other, much like magnets.

Calcium, magnesium, sodium, potassium and other metals carry positive charges and are attracted to clay particles. The charges vary in electrical strength and ability to overcome the natural repulsion of clay particles.

Sodium for example cannot overcome the repulsion of clay particles. In solution, sodium becomes hydrated, that is, it balloons out

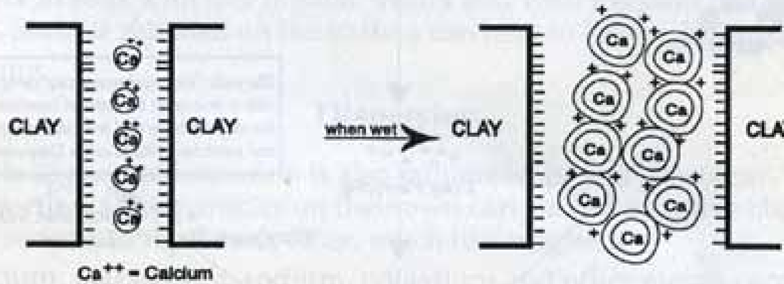

RAIN
Good soil structure
-good infiltration and air movement
(0.5 - 5 mm diameter)
Stable aggregate
Slaking is the process in which aggregates "explode" due to the pressure of air being trapped inside as they wet up thus forming micro aggregates
Slaking
Micro-aggregates
Dispersion
Micro-aggregates
The soils "electrical properties" may not be able to overcome the natural repulsion of the clay particles and breakdown into clay-size particles. This is calles Dispersion.
Clay Particles
Clay particles
(less than 0.001 mm diameter)
lack of tilth,
crusting, clodiness

(as shown in the diagram). As a result, the clay particles are spread apart.



This means the soil is easily dispersed when wet i.e. the aggregates break down into individual clay, silt and sand particles. This process usually takes hours as opposed to minutes for slaking. The dispersion of clay causes the cloudiness effect in water. When the soil dries up,it forms a large 'concrete-like' lump. A high proportion of potassium and magnesium will also result in dispersion.

Calcium, on the other hand, can overcome dispersion. It is also hydrated but only to a limited extent. This results in the clay particles being much closer together and more calcium remaining in between the clay to overcome the repulsion of the negative charges.



This causes clay particles in solution to form clusters and not disperse. This is known as flocculation, a very important process forming the basis by which gypsum prevents crusting (gypsum being a good source of calcium). Gypsum, however, does not help in aggregate formation, this is a function of organic matter. Gypsum stops soil from crusting but is not a 'glue' binding soil particles into aggregates. Gypsum and lime are less effective if crusting results from slaking.

HOW IS SOIL STRUCTURE CHANGED?

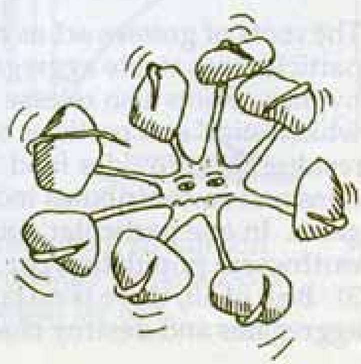
Farming practices have contributed to soil structure problems. By analysing the situation, strategies can now be developed which will actually improve soil matters.

(1) Soil Fauna and Micro-Organisms

The role of living organisms in aggregate formation should not be underestimated. It is possible for more than half of all stable aggregates formed in the soil surface to have originated from the activities of soil organisms.

Earthworms are the major living organisms which contribute to soil structure. Soil which has passed through worms is well mixed with organic material and is held together into good sized aggregates. Earthworm decomposition products also stimulate microbial activity so promoting further aggregate formation (as will be explained shortly). Aggregates formed by earthworm activity are usually more stable than other aggregates and contain more organic matter than the surrounding soil.

Micro-organisms also make a big contribution to good soil structure. Bacterial activity helps to bind particles of clay. The principal micro-organisms involved in aggregate formation, however, are fungi; fungal threads (hyphae) entangle soil particles so holding them together.



Fungi also produce polysaccharides to which clay particles can become attached. Thus the living component of soil is very important. To maintain it we need to keep the soil moist (retain stubble) and supply food both as living roots and plant material, in order for organisms to stabilize aggregates and help our soil. This was clearly proven in a Shepparton orchard where earthworm numbers increased from 150 per square metre to 2000 per square metre once adequate food and water was present (for more detail see reference no. 2).

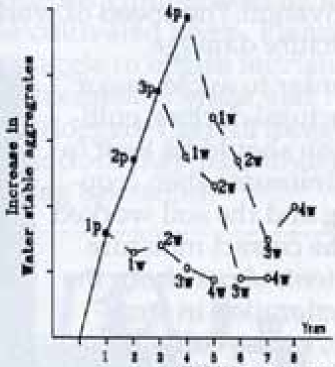
(2) Organic Matter

Organic matter, as has already been noted, is the key to good soil structure. The best means of increasing organic matter is by ***well managed*** pastures which consist of prolific plant growth, to the extent that the soil surface is blanketed by a mass of leaves. This protects the soil surface from raindrop impact and the resultant crusting. With a decrease in crusting, water entry and storage is improved.

The roots of grasses act as binding agents, which entangle soil particles into stable aggregates, much in the same way as fungal hyphae. Roots also release organic residues (gel) such as mucilage which 'stick' soil particles together into aggregates. This organic residue also provides food for soil organisms and microbial populations and so contributes indirectly to an increase in stable aggregates. In one particular situation, 8 years of pasture increased the earthworm population per hectare by 1 $^1/_2$ million (see reference no. 3). Best of all, there is no cultivation in pastures to break down aggregates and destroy channels formed by the various organisms.

Soil structure is better after a pasture phase and worse after a cropping phase.

The benefits of pasture are illustrated in the graph. The vertical scale represents water stable aggregates which don't break apart when given reasonably vigorous agitation in water. These form under pasture quite quickly (the soild line 1P-2P-3P-4P) but decrease quite quickly under crops (wheat in this instance, 1W-2W-3W-4W) where 1P is the first year of pasture, 2W is the second year of wheat and so on.

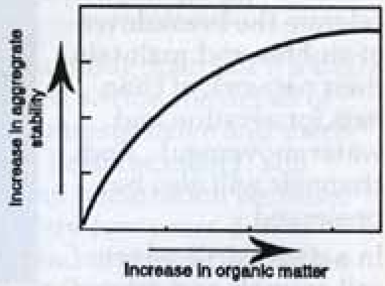


(ELLINGTON, 1981)

(3) Cultivation

The aim of cultivation is to kill weeds which compete with the preferred plant species, to control diseases and to produce a satisfactory seedbed. Problems with cultivation occur when the soil breaks into very fine particles and where the broken aggregates are not stable. During this process, protected parts of organic matter are exposed to attack by micro-organisms increasing the rate of soil breakdown. The network of roots and fungal threads is also broken apart.

Cultivation also removes crop residue thereby diminishing the food supply for soil animals and micro-organisms. Earthworm numbers are lowered under cultivation due to a decrease in soil moisture and destruction of the worm's habitat and channels (for more detail see reference no. 5). As a consequence of these processes soil stability declines. The relationship between soil stability and organic matter is shown in the diagram.



It follows that if organic matter can be maintained, so can soil structure. Australian soils under pasture usually contain 2-3 % organic matter. Soils under cultivation contain far less.

Timeliness of cultivation has a major influence on soil structure. Aggregates can be compressed into a plastic mess if cultivated too wet, while cultivating too dry pulverises the soil. The soil is too wet when wheel slip occurs or when the soil is indented by wheel tracks. The soil is too dry when large clods or dust results from cultivation.The speed of working will also affect the rate of soil structure damage.

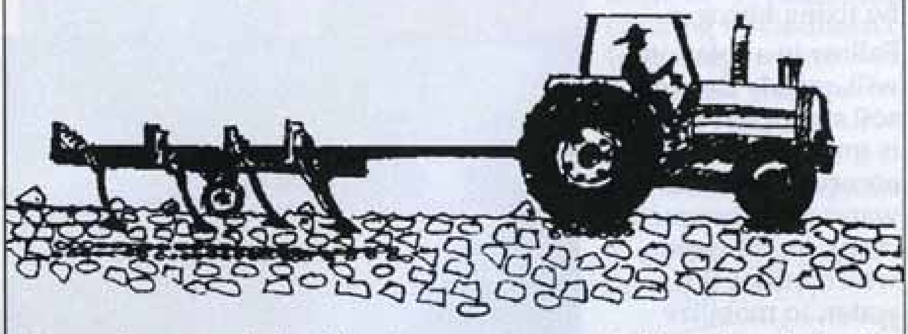
In order to avoid major structural decline, cultivation should be kept to a minimum when cropping and the soil worked at the correct moisture content. Apart from the deterioration in structure, excess cultivation costs time and money which could be more productively utilised.

From this point of view direct drilling is the ultimate procedure since cultivation is reduced to zero thereby causing the least damage to soil structure. Plant remains are retained and so encourage soil animals and micro-organisms which will stabilize aggregates, accelerate the breakdown of stubble and maintain their network of channels for aeration and water movement. Root channels will also be preserved.

In a direct drill system soil animals and micro-organisms do your cultivation. Less soil disturbance means that erosion is also minimized and crusting is reduced. As shown in the photograph, only the tip of the implement penetrates the soil during sowing. Presswheels are often used to offset the effects of poor depth control.

(4) *Compaction and Deep Ripping*

Nowadays, farms are much bigger and equipment/tractors have also grown in size. This has brought along another problem for our soils and that is LARGER AND HEAVIER MACHINERY INCREASE SOIL COMPACTION. This is further complicated by the formation of a plough pan just below the cultivated layer. Plants find it hard to grow roots through and struggle to obtain nutrients. In addition, soil compaction blocks the movement of water and restricts air diffusion when the soil is waterlogged. Careful measurement has shown that up to 80% of a paddock may pass under a tyre of some sort in a typical years' cropping operation.



Aggregates are crushed and in extreme cases a compacted layer forms below the tillage depth and under the tyres of heavy machinery.

Deep ripping will overcome the effects of a ploughpan but if a definite 'concrete-like' layer cannot be identified within the depth of root penetration, deep ripping will prove unresponsive and therefore uneconomic. When deep ripping has been necessary, soil moisture increases to deeper depth and root penetration becomes easier. Deep ripping may be necessary every few years due to cracks and pores disappearing with time and the onset of further compaction. Grazing animals can compact the soil so pastures may need to be ploughed and resown after some years.

Once again compaction can be avoided by minimizing cultivation, maintaining pathways for machinery movement (known as tram lines) and by not grazing susceptible areas when saturated.

(5) *Rotations*

A good crop rotation can help reduce the rate of organic matter decline thereby maintaining soil structure. The incorporation of a pasture phase, as has already been mentioned, will improve soil structure but a duration of 2-3 years is required for some soils.

An alternation of grain legumes, oilseeds and cereals will achieve control of diseases and weeds resulting in higher yielding crops with vigorous root systems thus increasing the organic matter input into the soil. Oilseeds, in particular, have a strong tap root system capable of breaking through hardpans; this improves water availability and root penetration for subsequent crops.

Grain legumes and legume pastures also contribute to soil fertility by fixing nitrogen.

Fallow in a rotation will quickly destroy soil structure. Fallow is undertaken to accumulate stored water for subsequent crops, to kill weeds which utilize this water, to mobilize nitrogen and to control diseases. During fallow, the soil is left bare for nine months which, in effect, is nine months without an organic matter input and in which numerous cultivation occurs. This practice is probably only sustainable on soils such as the Wimmera grey clays with their high moisture holding capacity and chemical properties which maintain soil stability rendering organic matter of less importance. Cultivation can be minimized, however, by chemical fallowing with the added benefits of better erosion control, a return of organic matter to the soil and better water infiltration.

(6) *Gypsum*

Gypsum will maintain soil structure by inhibiting dispersion. It is the calcium in gypsum which replaces sodium in the soil, consequently crusting is reduced.

By reducing crusting, gypsum improves water infiltration, decreases waterlogging thereby improving paddock access after rain, reduces wear on implements and improves fuel consumption efficiency.

Persistence of original structure when treated with gypsum

Slaking and crusting of an unstable soil

Once dispersion has been reduced, it is vital to encourage a more stable bond with organic matter so that aggregate formation may persist in the long term, i.e. gypsum stops crusting but it doesn't help in aggregate formation. Furthermore, gypsum is quickly leached out of the soil and needs to be applied every 2-3 years. Relying solely on gypsum encourages the decline in organic matter.

Because cultivation destroys organic matter, it is clear that soils requiring gypsum SHOULD NOT BE EXCESSIVELY CULTIVATED. Cultivation after gypsum application is like eating cream cakes while dieting - it defeats the purpose.

A common misconception is that gypsum needs to be mixed into the soil by cultivation. In fact, rain will wash it in quite quickly.

The likelihood of a soil response to gypsum can be predicted from a dispersion test available from the Department of Agriculture and Rural Affairs.

(7) *Stubble*

Stubble retention is equivalent to composting the paddock. That is, straw or stems left after harvest are returned to the soil rather than burnt.

The main effect of stubble (mulch) is to reduce the impact of wind and water on the soil. Raindrop impact on bare soil is like a bomb, breaking up soil aggregates and dispersing the fine clay particles into a dense crust. Surface crusts of 1 mm thickness are enough to block the movement of oxygen and carbon dioxide through the soil.

Retaining stubble on the surface will result in better water entry, a reduction in water loss by evaporation and higher crop emergence. In the Wimmera, an additional 20 mm of rain was stored in the soil due to retained stubble and this resulted in a yield increase of 27% at one location (for more detail see reference no. 4).

A higher moisture content means that crops can be sown earlier and are better adapted to a dry season. Keeping the soil moist for a longer period encourages microbial production of stabilizing bonds. For example, at Rutherglen, total worm numbers increased from 123 per square metre to 275 per square metre when wheat stubble was retained (for more detail see reference no. 5).

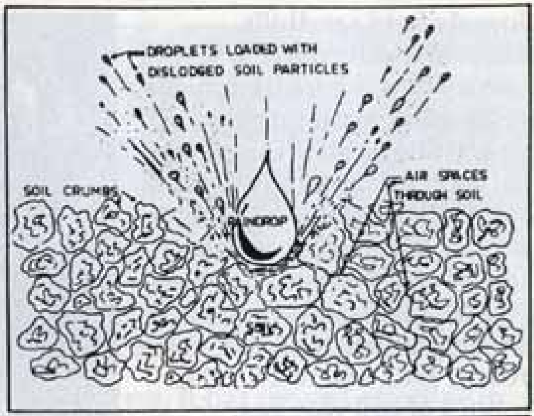
Attempts to incorporate stubble below ground will not conserve soil moisture and will actually reduce soil organic matter levels due to tillage increasing the rate of organic matter breakdown. Soil organisms will incorporate stubble for you.

Stubble decreases the risk of soil erosion, as illustrated opposite.

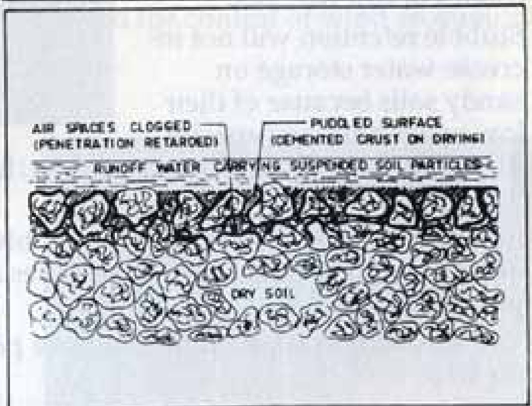
In addition, wind erosion may be prevented by retaining stubble. Loss of soil by wind erosion occurs predominantly in the Mallee. It is seen as drifting sand covering fences and, on occasions, as dust storms carried over the landscape. Wind erosion begins on the

Figure 1: How mulch reduces runoff

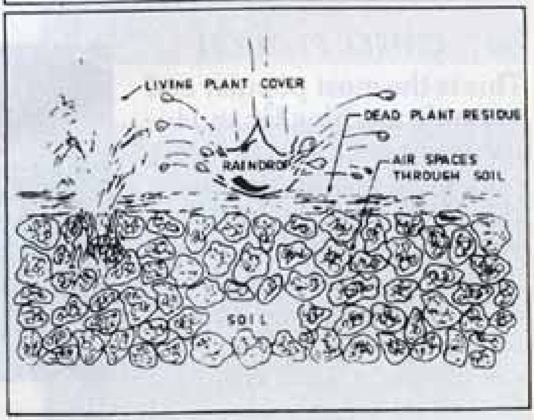
RAINDROP IMPACT ON BARE SOIL IS THE INITIAL CAUSE OF SOIL EROSION.



RUN-OFF WATER CAUSES DAMAGE TO FENCES, ROADS AND BUILDINGS. THE CARRIED SOIL CAUSES SILTING OF ROADS, WATER STORAGES AND PORT FACILITIES.

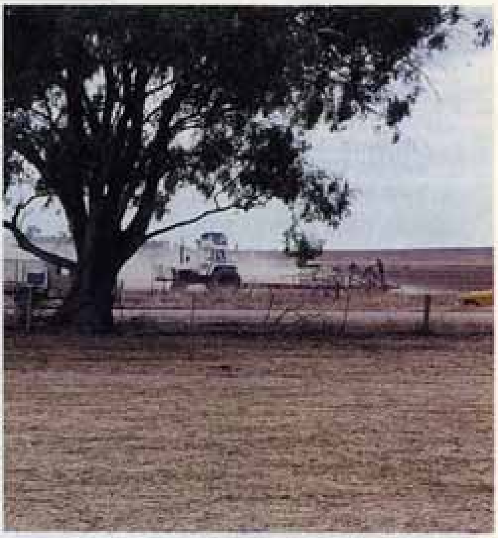


SURFACE COVER REDUCES RAINDROP IMPACT AND REDUCES SOIL EROSION.



Courtesy Queensland Department of Primary Industry.

loosely held sandhills (dunes), particularly where the surface is bare. It may be reduced by maintaining a rough surface but this is very difficult on the sandy soils of the Mallee. Retaining stubble on the surface and chemical fallow will prove more effective and will prevent dust storms similar to that of February, 1983 where 140,000 tonnes of soil was lost.



Stubble retention will not increase water storage on sandy soils because of their low water holding capacity. The advantage of stubble retention in this situation is the control of wind erosion.

Equipment designed for handling stubble must be capable of dealing with high volumes of crop residues and have effective seed placement.

The following equipment has become popular for stubble management.

(a) CHISEL PLOUGH

This is the most popular and versatile machine for stubble management but may incorporate too much stubble. It can be used in conjunction with a rod-weeder or rotary harrow. It is suited to sticky clay soils which disc drills find difficult.

(b)   BLADE PLOUGH

The soil flows over the blade while the roots of weeds are cut. The trash on the surface remains undisturbed. Problems may occur on heavy soils which are damp underneath and dry at the top (trash/weeds stick to blade). It is more effective on light (sandy) soils which drain rapidly and allow quick paddock access. It has proved effective in conservation cropping, particularly in the control of wind erosion.

(c)   TRASH RETAINING DRILL

This is a very advanced combine cultivator seed drill which is very economic and versatile. It is an all purpose drill suited to stubble farming, direct drilling and conventional farming. For effective stubble handling, the straw must be slashed into small lengths (10-15 cm).

(d)   ROTARY HARROW

This maintains stubble on the surface and also gives effective weed control. It can be used in primary tillage giving a good breakdown of clods and is capable of levelling ridges. It has proved popular on loam to sandy loam soils.

(e) DISC DRILL

This has proved successful on sand to sandy loam soil. The disc drill is able to cut heavy straw making stubble retention possible. For maximum effectiveness, the soil surface needs to be dry in order to avoid blockages. The Ryans disc drill can successfully sow through heavy quantities of straw (8-10 t/ha) but the triple disc drill is limited to wheat stubble of 4 t/ha.

MANAGEMENT OPTIONS

We have just seen what soil structure is all about. The question we now ask is WHAT ARE OUR MANAGEMENT OPTIONS for developing and maintaining good soil structure. The following list tells us in decreasing order of effectiveness.

1. A pasture phase of several years duration.
2. Direct drilling with retained stubble.
3. Direct drilling with stubble burnt.
4. Reduced tillage with retained stubble.
5. Reduced tillage with stubble burnt.
6. Reduced tillage with stubble incorporated.
7. Full tillage with stubble burnt.
8. Full tillage plus long fallow.

Gypsum is an important tool in all these options when soil is responsive but should be seen as a short term measure while organic matter bonding is being increased. The use of crops in rotation has a significant role to play.

Long fallowing must adversely affect soil structure because it reduces the input of organic matter.

We can confidently say that continuous cropping is only sustainable in the long term on the friable clays, as these soils seem to maintain adequate structure even at low organic matter levels. Soil structure and organic matter will decline in other soils under ALL systems except well managed pasture, the only difference between them being the rate of decline.

The bottom line

(1) If you have a friable clay, structure problems are not critical, but you should look after this asset as they may eventually develop.

(2) With the other soils a whole spectrum of options exist. If the soil is "nearly friable clay", a change to minimum tillage may produce sufficient aggregation for good crop growth.

If your soil has good structure, but is held together weakly, then adopt practices which minimize its disturbance and maintain an adequate pasture phase in your rotation.

If your soil has very poor structure, you may need to add gypsum and enter an extended pasture phase. When the structure has built up, a limited period of cropping using minimum disturbance will be possible.

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