Organic soil management in New Zealand

1. Introduction

Soil management is a cornerstone of organic philosophy. The soil is viewed as the foundation upon which the farming system is built and unless it is in 'good heart' there are likely to be both short and long term problems.

Appropriate soil management is therefore fundamental to successful organic farming, and one where organic practices can differ considerably from conventional methods. Organic management techniques aim to create a biologically active soil with good structure, high nutrient and humus levels. These attributes create conditions that produce high quality crops and help reduce nutrient leaching by holding nutrients in the soil humus. Soil erosion and subsequent loss is also reduced by increasing the porosity and water holding capacity of the soil. Soil management on an organic property also plays a vital role in weed, pest and disease, control, particularly soil borne pests and diseases.

2. Standards

There are no concise guidelines for soil management in the New Zealand Biological Producers Council's (BPC) Certified *Bio-Gro* Organic Production Standards. There are items in several sections on areas such as manure policy and crop diversity for example, however there are no detailed lists of approved cultivations, nutrient management and rotation design. The following section lists permitted and prohibited practices relevant to soil management as described in the BPC standards. Additional detail on suitable cultivation methods and rotation has been compiled from various standards including the International Federation of Organic Agriculture Movements (IFOAM) to act as guidelines of practices acceptable to the BPC.

2.1 Soil Management

- There should be a regular input of organic residues in the form of green manures, composts, and animal manures.
- Practices should ensure the continual activity of earthworms and other soil stabilising agents.
- As far as possible there should be a continuous protective covering of vegetation either cash crop or green manure.
- Cultivations should be kept to a minimum by the use of rotations, suitable equipment, and timing of cultivations.

2.2 Cultivation

- Cultivation should aim at deep loosening without inverting the soil profile and shallow mixing to incorporate crop residues and create a seed bed.
- Cultivations should avoid regular inversion of the soil profile.
- Avoid working the soil in adverse conditions, i.e. when very wet or dry.

- Deep loosening should be achieved by subsoiling / deep ripping and should be stabilised with green manure or crop as soon as possible.

2.3 Rotations

- Rotations should increase the level of organic matter in the soil, improve the soil structure, and maintain nutrient levels.
- A balance must be achieved between fertility building and exploitative cropping.
- Crops with differing root systems must be included.
- Rotations must include a leguminous crop.
- Plants with similar pest and disease susceptibility must be separated by a suitable time interval.
- Vary weed susceptible crops with weed suppressing crops.
- Utilise green manures as catch crops or under sowing to minimise the time then soil is without protective vegetation.

2.4 Plant and animal Manure Management

- The addition of organic matter to the soil shall not lead to the pollution of surface or subterranean waters.
- Plants and animals must not be subjected to excessive nitrate levels due to applying organic matter.
- Caution must be taken to ensure prohibited and restricted materials are not inadvertently brought onto the properties with manures, compost mulch or other organic materials.
- Animal manures both solid and liquid must go through acceptable aerobic or anaerobic decomposition process, eg hot composting, liquid brews and biodigesters.
- Composts should come from certified properties. Compost from conventional properties should under go a hot composting process.
- Mulch material from conventional sources must not of had prohibited substances applied to it. Documentation will be required to prove this and residue tests may be required
- Every effort must be made to ensure brought-on materials are free from contamination from prohibited materials.
- Materials with a relatively high heavy metal content must not cause the heavy metal content of the soil to increase over time.
- Heavy metals in manures and composts must not exceed

Metal	mg/kg
Zinc	1000
Copper	400
Nickel	100
Cadmium	10
Lead	250
Mercury	2

- Where an essential trace element is deficient this may be corrected by the application of permitted or Council approved restricted materials at specified amounts.
- Approved biological activators can be used, for example Bio-Dynamic preparations, microbial activators and plant based preparations. These must no be adulterated with restricted or prohibited materials.

2.5 Fertilisers

- The underlying principal is that all fertilisers must be worked on by soil or compost organisms before the nutrients are plant assimilated. Heavy metal analysis may be required. The following is a list of permitted materials.

  Calcium Sulphate (gypsum)
  Elemental sulphur
  Feldspar

Limestone
Rock minerals eg durite, magnesite, borax chalk.
Sulphur pelletised with bentonite
Unadulterated seaweed and fish products
Unrefined unadulterated rock or sea salt
Dolomite (Magnesium limestone)
Glauconite (greensands)
Rock phosphate

- The following fertilisers are restricted, i.e. they can only be used if no suitable permitted materials are available and only after the BPC or its inspectors have been notified.
  Basic slag
  Langbeinite rock (Potassium, magnesium sulphate)
  Magnesium sulphate (Epson salt)
  Potassium sulphate (Regular use may preclude full *Bio-Gro)*
  Blood, bone and feather products unless they have undergone a hot composting or other suitable treatment.

3. Soil Fertility Management

Soil fertility management in an organic system relies on a range of practices. This includes rotations of different crops and livestock, green manures and breaks from cropping, attention to cultivation practices, and the application of animal manures and permitted fertilisers.

3.1 Rotation

Rotation plays a very important part in maintaining soil fertility management in organic production systems. The following are guidelines for designing a suitable rotation. They will have to be modified for particular soils, climates and cropping systems.

- Deep rooting crops should follow shallow rooting crops.
- Alternate between crops with high and low root biomass.
- Nitrogen fixing crops should alternate with nitrogen fixing crops.
- When ever possible catch crops, green manures and under sowing should be used to keep the soil covered especially in winter.
- Alternate between weed suppressing and weed susceptible crops.
- Alternate between leaf and straw crops.
- Where a soil borne pest or disease exists there must be a suitable break between susceptible crops. Host weeds must also be controlled.
- Use mixed species or cultivar crops where possible.
- Alternate between spring and autumn sown crops.

Deep rooting crops bring up nutrients from lower levels, open the soil structure and improve drainage. High root biomass crops provide valuable food for soil organisms especially earthworms. Mixed lays with herb species are ideal for this. Ideally all the farms nitrogen requirements should be met from nitrogen fixation. Alternation between straw and leaf crops is important for weed suppression. Mixed species / cultivar cropping is where two crops are grown at the same time for example cereals and beans. This breaks the crop monoculture and gives greater yield than the two crops grown separately. The two crops must be separable if they are to be sold separately. Alternating spring and autumn sown crops is important for pest and weed management.

The key to successful rotations is diversity in space and particularly time. In cropping situations resting phases preferably under a grass, clover / Lucerne and herb lay for a year or more (depending on soil type and cropping history) is important.

3.2 Earthworms

These play a very important role in organics, both as a symbol of the organic philosophy and as a vitally important agent in creating a productive soil. There are many species of worms a few of which play a role in soil maintenance. A wide range of earthworms also exist and these vary in there effectiveness. The exotic *Lumbricus terrestris* is considerably more effective than native species.

Earthworms play a crucial role in maintaining soil structure. When they ingest soil particles they combine clay, lime and organic matter to form water stable soil aggregates. Plant roots are then able to fully utilise the nutrient and water reserves in that soil. Earthworms can process up to 40 tonnes of dry earth / hectare annually, which is equivalent to 0.5 cm of soil. They also create drainage and aeration channels, bring up nutrients from lower levels, and speed up the destruction of crop wastes.

Chemical fertilisers and pesticides can have an adverse effect on worm populations. This leads to a loss of soil structure, reduced incorporation of organic matter, increased compaction and associated problems.

To maintain a healthy earthworm population there must be regular input of organic matter to the soil, both manure and crop residues. Resting phases such as grass and herb lays are particularly beneficial. Soil pH must be maintained, a pH below 5.0 will reduce earthworm activity and there effectiveness. Cultivations especially with powered equipment is detrimental to earthworms and should be kept to a minimum. Soil inversion (i.e. ploughing) has very adverse effect on earthworm populations and should be kept as shallow and as infrequent as possible.

3.3 Cultivations

Organic production methods often require different cultivation techniques to conventional production. The principals of organic cultivations can be summed up in the phrase " Shallow turning and deep loosening". Shallow being less than 10 cm and deep more than 10 cm. The exact cultivations required depend on the requirements of the crop and the previous cropping history. For many cereal crops and the establishment of swards no tillage or minimal till operations can be used. The use of no till over several years may lead to increasing compaction. This can be remedied by deep loosening with subsoilers or rippers.

The number of passes over the ground should be kept to an absolute minimum. This reduces soil compaction and time. The use of no or minimal till operations is particularly valuable to achieve this.

3.3.1 Ploughing

Deep ploughing especially on a regular basis is not acceptable in an organic system and is detrimental to the soil and earthworm populations in particular. Shallow ploughing to bury trash or weeds is acceptable but not on a regular basis. Other options for trash destruction include disks and powered equipment.

3.3.2 Powered cultivators

There are advantages and disadvantages with using powered equipment. On the beneficial side they can reduce, often considerably, the number of passes required to achieve a suitable tilth, reducing compaction and time taken. They can also cause considerable damage to the soil structure due to the large amounts of energy put into the soil. The rotary hoe in particular causes considerable damage to soil structure, kills earthworms, creates a smeared, compacted cultivation layer and incorporates excess air into the soil, leading to rapid oxidating of soil humus.

3.4 Nutrients

Organic methods of maintaining nutrient levels work at a much slower rate than conventional ones. The organic philosophy is to ‘feed the soil and the soil will then feed the plant’. Because of this slower rate of action it is essential to regularly monitor soil nutrient levels so problems can be prempted and prevented. It is important to test for micro as well as major nutrients as deficiencies in these though rarer can have equally adverse effects on crops.

3.4.1 Nitrogen

Nitrogen is an essential ingredient of amino acids the building blocks of proteins.

Nitrogen is often the limiting factor for crop growth which is why the addition of nitrogenous fertiliser by conventional farmers can show considerable yield increases. Organic production is designed to **restrict the luxury uptake** of nitrogen by plants. It tries to avoid fast growing, weak plants, as these have reduced resistance to pests, disease, lower nutritional quality and possible toxicity problems due to excess nitrate levels. This should be kept in mind when considering nitrogen requirements for an organic property.

The main source of nitrogen for organic systems is leguminous plants. In a cropping situation it not be enough to just have leguminous cash crops, because much of the nitrogen fixed by these crops is lost when the crop leaves the farm. Leguminous green manures will be required as well.

Spreading farm produced manures is an acceptable way of targeting areas where nitrogen is required. The regular use of brought in manures is restricted by the BPC. Animal wastes have to be composted, direct application require BPC permission. The BPC has no detailed guidelines on the quantity of manure that can be applied apart from the statement "manure application should not lead to pollution of surface or subterranean waters, nor shall plants and animals be subjected to excessive nitrates due to organic matter additions".

Animal wastes especially fresh or lightly composted wastes have high levels of soluble nitrogen. Care must be taken when applying these materials. If they are applied to bare ground a crop or green manure should be grown immediately to utilise the soluble nitrogen. Applications should preferably be done in the spring or summer when there is lower rainfall and therefore reduced leaching risks and higher rates of take up by plants. Avoid applying in autumn and winter as most of the nitrogen will be lost from the system.

3.4.2 Phosphorus

Phosphorus plays a fundamental role in plant enzyme activity and energy transfer in the cells. Deficiency symptoms can be difficult to detect. It is equally vital in animals where it is used in bones and many proteins.

The availability and uptake of phosphorus is linked to soil pH and mycorrhizal associations. Plants take up most of their phosphorus in the form of inorganic phosphate ions. A pH of 6-7 provides the best conditions for uptake by plants. Problems can therefore exist on calcareous soils with lower pH levels. Phosphorus which is tied up in organic forms is not normally available to plants. Care should be taken when rapidly building up humus on soils with low phosphorus that too much phosphorus dose not become locked up in an unavailable form.

Mycorrhizal association can play an important role in organic production. The high levels of readily available nutrients in conventional systems reduces the need for mycorrhizae. In an organic system mycorrhizae considerably increase the uptake of phosphorus nitrogen potassium and calcium.

The main loss of phosphorus comes from crop removal. Losses from leaching, run off and erosion are smaller but can be a considerable drain over time.

Animal manures are an important source of phosphorus, with composted manures releasing the nutrient over several years compared to slurry which releases approximately 50% in the first year.

Green manures can accumulate phosphorus unavailable to other crops. Sufficient time for decomposition is essential to ensure that the accumulated phosphorus is in an available form.

3.4.3 Potassium

Potassium is a major plant nutrient with plants containing roughly equal amounts of potassium and Nitrogen. It is also vital in animals where it exists in greater amounts than sodium. Its availability from the soil is dependant on both the form of potassium and the relative amounts of other nutrients. The four forms are;

- Soil mineral component.
- Fixed potassium.
- Exchangeable potassium.
- Water soluble potassium.

Plants can only absorb potassium from solution, the level of which is readily topped up from exchangeable potassium. However the release of potassium from soil minerals and fixed potassium into the exchangeable state is very slow and dependant on soil type and parent material.

There is little or no loss of potassium via leaching, the main loss is from produce sold off the farm. Care should be taken to minimise the sale of materials such as straw and silage off farm. Plants vary in their ability to extract potassium from the soil. Grass is particularly effective and deficiency problems are most likely to occur where several crops of grass have been removed from a field without returning any nutrients by applying animal manures

Animal manure contains considerable potassium levels however careful composting and protection of the manure heap is needed otherwise much of the potassium can be lost.

Potassium sulphate and Langbeinite rock (potassium Magnesium Sulphate) can be used under *Bio-Gro* rules however these are restricted materials and regular use will jeopardise certification.

3.4.4 Sulphur

Sulphur is often regarded as a secondary element though it is required by crops in similar quantities to phosphorus and magnesium. It is a vital ingredient in many proteins and vitamins.

The majority (90%) of soil sulphur exists is soils in an organic form, with the rest as soluble sulphides and sulphates. It is the latter forms that plants can take up.

A large proportion of the sulphur lost via crop removal is replaced from the atmosphere by a range of means including weak sulphuric acid in rain, particles of sulphur falling on the soil, and direct absorption of sulphur gases by plants. Sulphur is often a constituent of other fertilisers (for example *calcium sulphate*.), this should be taken into account when considering sulphur requirements. If additional sulphur is required either elemental sulphur or sulphur pelletised with bentonite is permitted by the BPC.

When the organic form of sulphur is converted to a soluble state hydrogen ions are released which decreases soil pH. This should be considered when applying sulphur. This effect can be used to rectify overly alkaline soils where nutrients may be tied up, or where crop problems are occurring, for example scab on potatoes.

3.4.5 Calcium

Calcium has an important function both within plants, animals and the soil. It plays a vital role in ion exchange in living things and forms the major part of the skeleton in animals. In the soil it helps regulate the pH which effects the availability of other nutrients, the level and type of biological activity and the formation of a good soil structure.

pH should be in the region of about 6.5. Below 5.5 earthworm and microbial activity is much reduced. Above 7.5 the availability of many nutrients is restricted.

Calcium is easily applied in various forms of limestones, chalk, gypsum, and calcified seaweeds. All these sources will release their calcium at a slow rate and will take a year or more to have an effect. The choice of material depends on what other minerals are needed, and what is commercially available. Care should be exercised when choosing when to apply calcium in the rotation as it can have detrimental effects on some crops (for example scab in potatoes) and beneficial effects for others, for example club root control in brassicas.

3.4.6 Micronutrients

These are required in small amounts by plants and animals often being used in enzyme systems. They include iron manganese, copper, zinc, boron, chlorine, and molybdenum. If pH is within suitable levels (6-7) then micronutrient deficiencies are likely to be rare. Where deficiencies do show up in a crop and this is confirmed by soil testing then the BPC will allow rectification of the problem with suitable material. This will be in the form of a soil applied mineral or rock dust. Foliar sprays may be permitted but not on a long term basis. Some micronutrients become tied up with soil humus. If a soil is known to be marginal for a micronutrient close attention (for example annual testing) should be paid when raising the humus levels of the soil to prevent deficiencies occurring.

Most of the micronutrients can become toxic to plants and animals if present in excessive amounts. This is unusual but consideration should be given the micronutrient levels in fertiliser materials to ensure that a problem does not occur.

3.4.7 Heavy Metals

Excess heavy metals can have serious health consequences for both soil organisms, plants, livestock and humans. Conventional producers are experiencing problems with increasing levels of cadmium from superphosphate application, which is making some sheep kidneys unfit for human consumption. Once present in a soil they are very intransigent and can remain for thousands of years. Bio-Gro's rule for heavy metals is that any application to the land should not lead to a build up of these metals over time.

There are strict controls on the application of heavy metals to certified land to correct a deficiency .. Permission must first be gained from the BPC. They will require evidence that the application is required and may specify what form the application should take.

When brought in manures or mineral fertilisers are to be applied to certified land the BPC may require a heavy metal analysis to ensure that levels are within expectable levels. For details of the permissible levels see the section Plant and animal Manure Management page 2.

4. Issues Of Soils Physical Properties

The soil is a very complex mixture of chemically inert mineral particles, chemically active minerals, decaying organic matter and living organisms. All these constituents interact in many different ways to produce the characteristics of the soil. Some constituents can not be altered by the farmer, eg the size of mineral particles, while others can be manipulated, eg humus levels, to change the soils characteristics.

Organic husbandry places great emphasis on creating and maintaining good soil structure and humus levels. This is achieved by the use of different crop species in rotations, the use of composts, animal and green manures and cultivation practices.

4.1 Soil Texture

Soil texture is the proportion of the different sizes of mineral particles in the soil, i.e. sand, silt and clay. It has a major effect on soil structure, drainage, nutrient holding capacity and biological activity of a soil. Most soils contain a mixture of the three sizes of particles.

The higher the proportion of sand the more free draining the soil and the poorer the structure. As the proportion of clay increases, the soil is less free draining, greater levels of nutrients are held and the ‘stronger’ the soils structure in its resistance to slumping when wet. High levels of silt and sand increases the chance of the soil collapsing when waterlogged. Soils with a high silt content are prone to ‘capping’ after rain or irrigation if the humus levels are not high enough. They hold a lot of water and nutrients.

Silt, sand and larger particles are chemically inactive. Clay particles can hold plant nutrients and water in there structure. This means that clay soils will swell and shrink with increasing and decreasing water content. This is an important process in the formation of good soil structure and improved drainage.

Organic philosophy states that crops should be matched to the soils and climates of a district. As it is not possible for organic producers to alter the soil texture, they need to choose cropping and or livestock systems that suit the soil. There are no specific rules in the BPC standards regarding this. It is left to individual inspectors to comment whether a particular activity is questionable or not.

4.2 Soil Structure

Soils structure is the way sand silt and clay and other soil particles form aggregated clumps and pore spaces in the soil matrix. A good soil structure is essential for organic production. It provides optimal conditions for plant growth by providing free access to nutrients, water and oxygen and has considerably greater resistance to erosion and other detrimental effects.

A good soil is described as “a water stable, organic enriched, granular structure where all the water reserves within aggregates can be fully exploited by root hairs and the space between aggregates will be large enough to allow rapid drainage, to admit air, and facilitate the deep penetration of roots”. (Elm Farm Research Center; The Soil, 1984)

The BPC standards are clear in regard to soil structure,. Soil fertility, soil organic matter and soil structure are of paramount importance (Section F1.2 from the BPC standards). BPC inspectors will expect to see improvement and maintenance of soil structure on organic properties.

The maintenance of pore space is an important part of building good structure. Pore spaces are classified in two sizes macro and micro pores. Macro pores are the large holes and spaces in the soil such as earthworm burrows that allow rapid drainage of water and free entry of air and oxygen. Micro pores exist between silt and clay particles and are essential for holding water and nutrients in the soil. The ideal ratio of macro:micro pore space in 30:70%. Sands typically have too much macro pores space and consequently hold less water and nutrients. Silts have too much micro pore space and are prone to waterlogging and compaction.

The formation of stable soil aggregates is equally important. The same factors that improves pore spaces also improves aggregation. High humus and biological activity in the soil, especially earthworms, is vital. Crop roots particularly swards are very effective. The maintenance of the correct pH is equally important. Lime is essential to help bind the soil particles together, and is vital for earthworms and soil microbial populations. Appropriate cultivation can help improve structure but inappropriate cultivation can severely damage it. Repeated cycles of wetting and drying, and freeze thaw also improve soil structure.

4.3 Soil Water and Air

Water has three primary functions in the soil. To satisfy plant demands, as a carrier for dissolved plant nutrients, and a factor in soil air and temperature behaviour. Water is retained in healthy soils at or below field capacity in the micro pore spaces and in clay particles. Plants can extract a considerable amount but not all of this water. A point is reached where the soil holds onto the water with as much force as the plant can exert to extract it. Once this point is passed the plant will wilt.

Air in particular oxygen is essential for plant roots and soil microrganisms to survive. Many can survive temporary anaerobic conditions of a few hours or days but sustained periods without oxygen will kill them.

The availability of both air and water in the soil at the same time is governed by the soils texture and structure. A healthy soil with good aggregation will have sufficient macro pores to ensure that there is free gaseous exchange with the atmosphere and enough micro pores to hold enough water for the plants. Good structure will also allow capillary rise to occur where water from lower down the soil profile is drawn up to the root zone.

If the soils structure is poor with large aggregates then there will be a considerable reduction in macro pores and soil oxygen. This can lead to the production of toxic compounds from anaerobic respiration, and the death of soil organisms and plant roots. This will inturn lead to reductions in crop yields. Poor drainage will make the soil colder as water needs more energy to heat than air.

4.4 Soil Organic Matter

Soil organic matter includes both living organisms and dead material. It is essential for creating a good soil structure, and ensuring sufficient nutrient, water and oxygen availability. There are several different forms of organic matter with different properties, commonly divided into three types

- Active soil organic matter comprised of living organisms and rapidly decaying molecules. This turns over every two to three years.
- Slow organic matter contains dead organic matter that is resistant to decomposition with a turnover rate of twenty to forty years.
- Stable organic matter has a turnover of 500 to 1000 years and consists of very recalcitrant molecules.

These three types of soil organic matter come from different sources and have different effects.

Active organic matter originates from animal and plant material with low carbon nitrogen (C:N) ratios. Its rapid decomposition releases nutrients for the following crop, however it has little effect on soil structure.

The slow and stable fraction of organic matter originates from material with a high lignin content and higher C:N ratio. The quantity of lignin and other intransigent structural molecules appears to be far more important than the C:N ratio in determining the soil organic matter type. This must be taken into consideration when applying any organic matter residues. A balance must be sought between material with a high nitrogen and nutrient level and one with a high level of structural molecules like lignin. This is an important reason why green manure crops should contain a mixture of legumes and cereals as it achieves a balance of carbon, nitrogen and lignin.

Soil biological activity has an important role in pest and particularly disease management. Many soil organisms attack plant pathogens; in a biologically inactive soil pathogens can proliferate due to an abundant supply of host plants, a lack of competition for resources and low numbers of predatory organisms. In a biological active soil the reverse is true; while the pest or disease will be present it will have to compete harder for resources and face a much higher level of predation. In many cases this is contrary to conventional wisdom. It some instances it can take some time to build up sufficient soil biological activity to achieve this effect. The conversion period can see increased problems from soil borne pest as the conventional control is removed and the organic one becomes established. Particular care must be taken on soils where known problems exist, avoidance of susceptible crops or land is the best option.

The main methods to increase soil humus levels in an organic system, are the use of green manures, return of crop residues to the soil, and the integration of animals and cropping in the farm system.

4.4.1 Green manures

The term green manure is used to describe a wide variety of plants that are grown and the whole plant incorporated back into the soil. The nutrients the plant has assimilated during its life are returned to the soil in a stable, available form for the next crop. The level of soil humus is also raised as is soil biological activity, due the nutrients and the large amounts of energy stored in the crop becoming available to soil life.

Green manures do not have a strict classification but they are often divided into nitrogen fixing (i.e. leguminous) and non nitrogen fixing types and by the season and or length of time they need to grow. Leguminous green manures are vital in an organic system for replenishing nitrogen. It is rarely adequate to rely on crop legumes to supply all the nitrogen required by the system as most of it will be removed with the crop. Commonly used legumes include peas, beans, lupins, trefoil (*Medicago lupulina*) clovers and lucerne. The quickest growing and short term ones are listed first and progress to longer term species. Ideally a mix of species should be grown and the following are often mixed with legumes. Buckwheat, phacelia, mustard, fodder turnips, cereals, (for example oats), sunflowers, grasses. Depending on the soil and cropping system both short term (2-3 months) and long term (1+ years) green manures will be required. Short term crops will help protect the soil and conserve nutrients but longer term crops will be needed in the rotation to restore the soil structure and increase nutrient reserves.

4.5 Soil Compaction

Compaction is an increase in the density of the soil with a corresponding reduction in the pore space (particularly macro pore.) It makes the soil considerably less favourable for the growth of plants. It is a problem on both conventional and organic properties and is caused by the following related factors. The soil texture, structure, water content and the load placed on the soil by livestock and equipment.

The proportion of sand silt and clay affects how prone a soil is to compaction. Sandy and stony soils have a much greater level of resistance than silt or clay soils. Soils with a good structure will be more resistant to compaction than weak soils. Compaction increases with increasing soil moisture levels.

The methods used for reducing compaction and undoing damage caused are similar to conventional practices. The maintenance of a healthy soil with good structure is the first step. This requires regular addition of organic matter and the correct nutrient and pH levels as discussed previously.

Timeliness of cultivations and stocking is important. Avoid working or putting stock on a field which is to wet or waterlogged. This is not always possible particularly at harvest time but the resulting damage can take three or more years to reverse at considerable time and expense. If such situations frequently arise then the cropping / livestock system my need revising to reduce such occurrences.

The type of equipment used has a major effect on compaction. Machinery especially tractors should be as small as possible for the job in hand, any unnecessary weights and ballast should be removed. Consideration should be given to using double wheels and or low pressure tyres. In many instances it is traction rather than power that limits a tractors ability to pull equipment and the extra traction gained with double wheels and or four wheel drive can allow the use of a lighter tractor.

There are increasing numbers of tractors available that can or have front three point linkages. These vary from standard agricultural tractors (eg Deutz) to specialist horticultural tool carriers (eg Fendt). The use of front and rear mounted equipment can reduce the number of field passes by half and hence compaction. There are also considerable cost and time savings depending on how frequently the equipment is used.

Cultivators vary in the amounts of compaction they create. The plough is possibly the worst offender especially if the tractor runs in the furrow rather than on the land. There is considerable smearing and compaction beneath the plough which leads to the formation of a hard dense impervious plough pan. Rotary hoes also cause compaction and smearing just below blade depth.

Draft equipment (for example disks, harrows and rollertillers) create less compaction particularly pans. However more passes of the field may be required to achieve a satisfactory tilth leading to increased compaction from wheelings. A balance should be struck between the use of powered and draft equipment.

Sub soiling and deep ripping can be very effective at reducing compaction damage. There are a wide range of implements available for this task, basic requirements should be to have as low a draft as possible, with maximum shattering. Current trends in subsoiler design are moving towards larger 'wings' on the side of the tine and a smaller front share. Considerable care must be taken with subsoilers as their use in non-ideal conditions can worsen compaction rather than alleviate it. The soil should be dry to moist down to the proposed depth of subsoiling. In hard conditions it is better to progressively increase the depth of working rather than trying to go as deep as possible in the first go. This can be achieved by making several passes at progressively greater depth or preferably by having two or three banks of tines getting progressively deeper. This will often reduce total draft rather than increase it and will produce a much better effect. Subsoiling should be immediately followed with the planting of a crop or green manure to stabilise the soil and take up released nutrients.

For all equipment the depth of operation should be regularly varied. If any type of equipment is repeatably used at the same depth then problems will occur just below that depth. Alternating between different types of implement is also advantageous.

For intensive vegetables the use of the 'bed system' or ridges where tractor wheels always run in the same place, keeping the area between the wheels uncompacted is highly recommended. These can be kept in place for several years if required.

4.6 Surface capping (crusting)

Capping is caused by rain and or irrigation destroying the structure on the surface of silty soils. It can be a major impediment to seedling emergence. A thick cap will stop all but the strongest and largest seedlings emerging with consequential effects on plant stands and yields. Capping is a sign of poor soil structure which is frequently due to low humus levels and too much cultivation either in the number of passes or the excessive use of powered equipment. Ploughing also increases capping by bringing up soil with poorer structure, lower humus levels and burying plant residues that protect the soil surface.

The use of ‘rain guns’ and other irrigators that produce large droplets and or throw the water some distance is likely to produce a soil cap. The larger the droplets and the faster they are travelling the more energy released when they impact on the soil, causing more damage. If water is applied faster than it can infiltrate the soil it will cause ponding and therefore capping.

To avoid capping in an organic system the first and continuing priority is the maintenance of a well structured soil with adequate humus nutrient and pH levels. A soil in good heart will resist capping better than a poorly structure soil. The soil surface should be protected by plants or mulch. Leaving land bare for long periods, particularly overwinter, is unacceptable. If crops are not being grown green manures must be planted to protect the soil surface. Ploughing and other soil inverting cultivations should be avoided.

Cultivations should be kept to a minimum, particularly the rotary hoe, as this causes considerable damage to soil structure. Minimum or no till operations should be considered where applicable.

Irrigators should produce small water droplets close to the ground to reduce the energy they contain (for example side shift irrigators). Application rates must be below the rate which the water can infiltrate the soil. The use of ‘rain guns’ on bare soil must be avoided.