CHAPTER 2

SOIL AND PASTURE MANAGEMENT

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2.0 SOIL AND PASTURE MANAGEMENT

Farm practices should maximise soil health and minimise soil compaction, soil erosion, soil contamination and emissions of greenhouse gases. Good soil management will also:

- Give unrestricted pasture root development, leading to good plant growth and vigour, less drought stress and better clover-N fixation
- Lessen the period of soil saturation and associated slow pasture growth and cow foot problems
- Improve seed germination, emergence and vigour when regrassing or cropping
- Reduce the risk of weed infestation
- Minimise topsoil loss through erosion and runoff, and reduce fertiliser requirements
- Minimise the need for remedial subsoiling or artificial drainage.

To manage soils appropriately, it is useful to know:

- The soil types on the farm
- What the properties of the soils are
- Appropriate management strategies for these soil types.

For more about soils and soil health, refer to 2.1.2 Assessing soil qualities and condition.

Pastures should also be managed to maintain a healthy sward that will maximise productivity while minimising soil damage through compaction and erosion. Maintaining a healthy pasture cover will also help reduce the establishment of weeds.

2.1 COMPACTION AND PUGGING

Dairying practices can cause soil compaction due to stocking pressure and machinery traffic, especially on wet soils. Cows exert a pressure of up to 350 kPa (i.e. over 50 psi). By comparison tractors exert a pressure of up to 200 kPa.

At moderate moisture levels, compaction of soils (compression of large pores) can occur even though this is often not visible. At high moisture levels, the hoof penetrates the soil more easily. The longer the soil remains wet, the deeper the penetration of the hoof, until deformation, called pugging, occurs. Compaction may also occur at deeper levels beneath the pugged zone.

When pugging is severe, the topsoil becomes a slurry, and pasture is also damaged. Production declines after pugging due to the following:

- Compaction of surface soil leading to poor infiltration and waterlogging. If a soil is partially pugged early in the winter then water will tend to remain on the paddock surface for longer. As a result, the soil will remain softer and wetter and the hooves of grazing animals will cause ongoing damage during subsequent grazings
- Crushing and bruising of leaves and stems, damage to roots and burial of plants in the mud make the pasture unpalatable and irretrievable to stock. Utilisation can be reduced by 20 to 40%
- Poor clover growth and nitrogen fixation (research indicates there can be a 60% drop with moderate treading and an 80% drop after severe pugging). This may last for months.

These effects create a direct reduction in subsequent pasture yield. As well as the damage to existing pasture and suppression of N-fixation, future pasture growth is limited by compaction due to physical resistance within the soil and anaerobic conditions that restrict root growth. Pasture production on damaged paddocks can be depressed by 20 to 80% for 4 to 8 months, depending on the soil type. Annual yield losses from damaged paddocks of above 30% have been reported in the Waikato, Manawatu and Taranaki.

Even with minimal pasture depression, the cost of lost feed is significant. On a typical Southland farm growing 12000 kg DM/ha, a 10% reduction over the whole farm represents 1200 kg DM/ha, which would be equivalent to $288/ha of lost production assuming a conversion rate of 60gMS/kg DM and a payout of $4/kg MS. As damage occurs mainly in winter and early spring, the impact on feed management may be even more severe. The importance of increasing feed supply on highly stocked farms is well known. Reducing pugging may be the cheapest means of increasing feed supply on some South Island farms.

Other consequences of pugging include the following:

- Weed invasion
- A need to regrass poorly performing paddocks
- More tractor passes required for seedbed preparation and sowing and greater fertiliser requirements. On severely compacted soils tillage costs are up to 340% higher and fertiliser costs (to ensure crop growth) are up to 280% higher
- Delays in sowing and harvest, and poor crop performance, with an increased susceptibility to root diseases and pest attack. On severely compacted soils, crop yields and pasture quality can be up to 45% lower
- Increased irrigation requirements
- Increased runoff and soil loss with overland flow of sediment, P and faecal material to waterways
- Increased release of greenhouse gases from compacted, waterlogged soils.

Compaction forces arise from wheels, plough soles, disc edges, rotary blades and livestock hooves. Cattle can do 3-4 times more damage to soils than sheep. On a grazed dairy farm, it is the management of heavyweight cattle in winter, spring and under irrigation that presents challenges. Research has shown that on dairy farms in Southland, where cattle are often wintered off the paddocks on a crop, paddock damage is more likely to occur in spring in wet conditions. On many North Island soils, considerable pugging damage occurs where stock are intensively block-grazed on-farm over winter.

Signs that compaction may be limiting pasture growth include greater fertiliser requirements to get the same pasture response, and poor pasture growth despite adequate soil test levels.

FIGURE 2.1-1

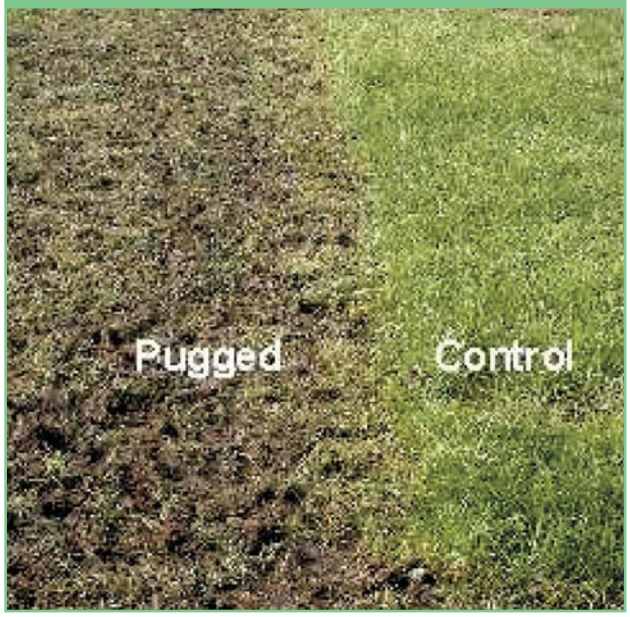
COMPACTED SOILS

Good soil condition | **Heavily compacted**

Source: Keith Betteridge, AgResearch

FIGURE 2.1-2

SURFACE PUGGING



Source: Keith Betteridge, AgResearch

2.1.1 Limiting pugging damage

The incidence of pugging damage is related to factors such as rainfall, soil properties, stocking rates/ grazing intensity, and duration of grazing on wet soils.

Some degree of pugging damage will occur on any soil when grazing animals are left in the paddock in wet conditions. However, different soils can tolerate varying intensities of grazing before becoming damaged. Pugging damage is more likely on Pallic and Recent soils in Southland and Otago, while Brown soils are less prone to damage. While pugging is less likely to occur on ash-derived Waikato soils, it is still possible.

The way a soil reacts to the application of pressure depends on the texture of the soil, how wet it is, and the shape of the contact area.

Heavy, poor draining soils are particularly susceptible to pugging damage because they remain wet for a long time after rainfall. Where there is a naturally compact subsoil that is slow to drain, the problem can be even worse (e.g. with silt or silt loams (Yellow Grey Earths)).

2.1.1.1 Winter grazing management

Winter grazing strategies to protect against pugging include the following:

- Build pasture cover leading into the wet season. Increased pasture cover, will protect against pugging, recognising that some pasture wastage may occur
- Make use of the differences in soil type, drainage, land slope and aspect using the 'strengths' of different soils on the farm at different times of the year. For example, use drier north and west slopes more in winter and less in summer to best utilise pasture growth and minimise soil damage. Plan to graze the wetter paddocks before the wettest part of the season, and again as soils dry out to reduce the number of times they are grazed in wet conditions
- Use a slow round, otherwise if the herd returns regularly, each time the pugging will be worse. If each paddock is subject to only a few grazings in the wet season, they suffer less overall damage. Also, the protective pasture cover will have regrown to its optimum height
- Shift stock off before soils get too wet in a rainfall event – play it safe and move them early
- Avoid grazing soils recently irrigated with effluent, preferably defer effluent irrigation until drier soil conditions occur

- Shift stock in the evening or before daybreak. Stock movement and subsequent pugging damage will increase after daybreak, particularly if stock are hungry
- Minimise the supplements that are fed out in paddocks sensitive to damage and feed out supplements before cows arrive
- Use the farm bike rather than heavy tractors
- Use on-off grazing, with a well designed and managed stand-off area, feed pad or other wintering system (refer to 6.6 Stand-off pads and feed pads)
- Winter stock off the farm. However, make sure stock are wintered off-farm on free-draining soils with sufficient grazing area or the problem will just be transferred!

2.1.1.2 Managing break feeding

Break feeding or block grazing is useful to restrict cow intake in order to more closely match feed demand and supply during the critical winter period. However, intensive grazing must be managed properly in order to avoid causing pasture and soil damage:

- Make breaks as square as possible. Avoid strip grazing. Long, thin breaks encourage stock to walk up and down the fence line. Use electric fences to break rectangular paddocks into squares
- Stay away from stock in wet conditions as much as practical. Any disturbance can cause them to pace and damage pastures and soils
- Start grazing from the back of the paddock. Long grass gives some protection against soil damage when stock or vehicles are driven over it. Also it is easier to get stock to move to fresh pasture by walking over pasture rather than over pugged, muddy soil
- Have several entrances to a paddock so that stock can walk over a different route each time they enter and leave. Consider having a gate in each paddock corner, dropping fences, and leaving grassed laneways to avoid walking over grazed areas
- Use a temporary back fence to prevent stock from back grazing and causing further damage to the previously grazed pasture. However, ensure stock have access to water, especially if hay or other dry feeds are being fed out
- Give a bigger break at night to reduce stocking intensity. Also, start a 24-hr break in the evening, so that it will be daylight when pasture cover becomes low and damage is more likely to be observed
- Use electric fences to protect damaged or sensitive areas such as bare patches, seeps and wetter soils.

2.1.1.3 On-off grazing

On-off grazing is the most effective method of minimising pasture and soil damage. It involves having stock on pasture or a crop for short periods of time – as little as 4 hours in very wet conditions. For the rest of the time stock stand on purpose built stand-off facilities or yards (refer 6.6 Stand-off pads and feed pads for construction information). Note, farm dairy yards can not be used as feed pads.

Research has shown that dairy cows consume approximately 70% of their pasture intake in the first 2 hours of grazing, and 80% in the first 4 hours. If the pre-grazing cover is good (i.e. 2700 - 3000 kg dry matter/ha), and allowance is adequate, cows will get maintenance feed requirements within 4 hours on pasture. Otherwise, stock will need supplementary feeds to maintain their intake at acceptable levels.

If possible, supplements should be fed on the feed pad rather than on the paddock to avoid feed wastage and damage to soils and pasture.

If farm dairy yards are used for standing off, the increased volume of effluent will need to be factored into the effluent treatment system. Also, stormwater diversion cannot be practised when the yards are dirty, and will create additional effluent volume.

Races and sacrifice paddocks are not recommended for standing off. Leaving cows on races can cause deterioration of the condition of the race and severe foot problems in cows. There are also issues in collecting the effluent from these sites, with a high risk of nutrients leaching to groundwater, or surface run-off reaching waterways. Compaction of sacrifice paddocks can not be remedied by summer cropping. Effects can last twelve months or more even in new pastures.

The construction of stand-off facilities is a substantial capital investment, but this can be cost-effective if depressed pasture yields as a result of compaction and pugging are taken into account. Research has shown that pad construction will pay off in wet seasons and on high-risk soils where a pad would be used for 50 days in the year (e.g. Pallic soils in Southland). The cost-benefit of stand-off facilities is less favourable on North Island ash soils if seasonal conditions mean that a stand-off pad is needed for less than 23 days.

Table 2.1-1 shows the advantages and disadvantages of stand-off facilities, particularly where combined with a facility to feed supplements. Note that some of the disadvantages can be avoided through good design (e.g. bullying and lameness) – refer to 6.6 Stand-off pads and feed pads.

TABLE 2.1-1

ADVANTAGES AND DISADVANTAGES OF PAD FACILITIES

Advantages	Disadvantages
• Less pugging of soil/pasture damage and more grass growth in spring • Higher stocking rates can be supported and cow condition is often better • Effluent can be collected and re-spread to paddocks for more effective nutrient use and to avoid leaching or runoff • Possible reduction in calf losses when calving on the pad (depending on stock density and the condition of the pad compared with the paddock) • Less wastage of supplement and ability to use specialised feed/ additives • Ability to maintain rotation length • If feed energy intake can be improved in late pregnancy/ early lactation, cows may cycle sooner after calving and improve reproductive performance • Protects farm drainage work (i.e. integrity of subsoiling and moling) • Reduced need for grazing off-farm • If well sheltered and/or roofed, prevents stock stress from weather extremes	• High initial capital outlay and exposure to financial risk • More time spent managing/feeding the herd • Requirement of regular cleaning, effluent disposal and maintenance/ replacement of bedding • Bullying of some animals (e.g. in-calf heifers) if insufficient space provided • Lameness if cows stand on hard surfaces for long periods • New management skills may be required to maintain production and animal health • May be greater use of supplements • Farm machinery may need to be upgraded to service the system • May increase the risk of mastitis

Although pads are usually used between May and September, they can be used during other times of the year when the soil becomes very wet. Also, calvers and dry cows may use the pad at night.

On a daily basis, the farmer is in the best position to decide on use through direct observation of soil conditions or a pugging assessment tool (refer to 2.1.2 Assessing soil qualities and condition). A cautious approach is often best - 'if in doubt, get stock off paddocks'. It may not be necessary to put all the stock on the pad.

On heavy, undrained soils animals will have to remain on the pad for longer until the soil dries out. When frosts occur while soils are still wet, the herd is best left on the pad.

2.1.1.4 Drainage

Installing and maintaining efficient drainage systems in susceptible paddocks will ensure that the paddocks remain wet for the shortest possible time following heavy rain. Improved drainage will reduce, but not eliminate the risk of treading damage. Even well-drained paddocks will pug during heavy rain events.

Talk to local consultants and farmers to determine the most appropriate drainage systems for any specific soil type and contour.

Where flat land is wet because of surface runoff from springs or hills, open or pipe drains can be used to intercept this runoff. This avoids the need for more drainage on the flat land below the hill or spring. All open drains should be fenced from stock to improve water quality and reduce drain maintenance.

Not all areas on the farm need to be drained, and drainage is not always cost-effective when ongoing drain maintenance is considered. Springs, seeps and swampy gullies perform valuable environmental services when fenced, as they filter runoff, reduce flood flows, and reduce dissolved nitrogen levels in water before it flows to streams.

One solution to poor drainage on flat land is mole drains. Flat land is usually poorly drained because surface water cannot move down through the soil, and is often made worse by a high winter water table.

Mole drains will last longer if they:

- Are in soils with a clay content greater than 20%
- Have been pulled in late spring or summer when soil temperatures are above 12ºC, the soil is moist but drying out, and the pasture is short. When a 'worm' can just be formed by rolling the soil to 3 mm thickness and 50 mm length, conditions are suitable for moling (refer to Figure 2.3-1). Conditions that are too wet for cultivating or subsoiling may still be suitable for moling
- Are not subject to surface pugging. Pugging destroys the soil structure and prevents water from moving through the soil profile. Overcoming serious pugging demands re-moling
- Have good outlets so that water does not lie around in the mole drain.

Where connecting moles to a pipe system, the pipes should be installed first and the mole drains pulled afterwards.

With any subsurface drainage, there is an increased risk of polluted water draining from paddocks through the soil into the drains and then flowing into waterways at the discharge point of the subsurface drainage system. This type of discharge by-passes the filtering effects of riparian areas. For this reason, effluent should not be irrigated over land with subsurface drainage where possible. If this land is used for effluent irrigation, the application depth and rate should be kept to a minimum, and irrigation should only occur in dry conditions. Grazing of drained soils should be carefully managed, especially when soils are wet. A final option for managing discharges from mole drains which may be applicable in some situations is to create an artificial wetland before the discharge reaches a natural waterway (refer to 4.1.4.4 Constructed wetlands to treat drain discharges).

2.1.1.5 Careful cultivation

Careful cultivation in the right conditions prevents subsoil compaction, maintains good soil structure for optimum growth and keeps production costs down. Subsoil compaction can have various effects on crop performance depending on conditions. Under dry conditions, the compacted soil restricts root growth so roots cannot reach water reserves below the compacted layer. Under wet conditions, the compacted layer impedes drainage and may create saturation of the root zone, slowing growth and increasing the risk of root diseases.

For further information on the management of soil cultivation, refer to 2.3 Cultivation and cropping.

2.1.2 Assessing soil qualities and condition

Soil qualities and soil health can be determined through soil testing and visual assessment, and recorded on a farm soil map to assist with planning. This is a valuable tool to avoid pugging and compaction damage and to manage runoff and leaching.

Important soil qualities to assess include:

- Soil texture – the amount of clay, silt and sand in the soil
- Soil structure – how well a soil holds together, without forming dense pans

- Drainage – indicated by the presence or absence of grey soil or rust coloured mottles in the soil profile, and the depth at which they occur
- Soil depth and pasture rooting depth.

Visual assessment can be done using Landcare Research's Visual Soil Assessment process. This is a kit with colour photographs and a recording sheet that requires only a spade, plastic sheet and bucket to carry out an assessment. Copies are available from Regional Councils and Dexcel.

Crop and Food Research have developed a Soil Quality Management System, which combines observations in the field and some simple tests.

AgResearch and Crop and Food Research have also put together a process for soil assessment specifically for dairy farmers known as the Dairy Soil Management System, combining physical, biological and chemical indicators.

Laboratory tests are available to assess the physical condition of the soil. Macroporosity is the best indicator of pugging damage. It measures the quantity of large pores in a soil core and is a good predictor of whether spring pasture growth will be limited by compaction. Macroporosity should not be less than around 10%. Research suggests that for every 1% increase in macroporosity in the 0-5 cm layer, an increase of 1.8% in relative pasture growth can be achieved.

Testing for macroporosity will be commonly available very soon. When sampling for macroporosity soil should be sampled at a consistent time of year (e.g. winter). The sample is taken at a depth of 0-10 cm with a special piece of equipment to retain the intact soil core.

Important soil properties and their relation to the farm business can be mapped using a package known as SUBS – Soils Underpinning Business Success (available from AgResearch). This package provides farmers with the skills to:

- Describe and map farm soils
- Link the properties of soils to their behaviour
- Catalogue the strengths and weaknesses of soils
- Assess the contribution each makes to the farm business
- Assess the current use of resources, including the current match of enterprises with the soil resources
- Analyse the need for capital changes (fertiliser, drainage, etc.)

AgResearch has also developed a system for daily decision-making about pugging damage. This involves a tool (the AgResearch penetrometer) and a graph on which to compare the results with predictions of probable pasture damage.

2.1.2.1 Management of different soils

Understanding your soils can help you manage them better for improved production and less environmental impact. For example, poorly drained soils have different issues and require different management to well drained soils (refer to Figure 2.1-3).

Poorly drained soils often have pale subsoils while well drained soils often have brown or orange-coloured subsoils.

Poorly drained, wet soils may contribute less nitrogen to groundwater because under wet soil conditions, soil bacteria convert nitrogen from urine into gaseous forms that are released to the air. However, these soils are more likely to create surface runoff, particularly if they are pugged. Therefore management attention should focus on careful grazing, not over-applying effluent and leaving grassy filter strips beside waterways.

FIGURE 2.1-3

POORLY DRAINED SOILS | WELL DRAINED SOILS

Source: Environment Waikato

Well-drained, light or sandy soils are less likely to have dirty runoff since the water drains through the soil, rather than running over the surface. However, nitrate in these soils is more prone to leaching to groundwater. Management practices for these soils might include the use of nitrification inhibitors, attention to N-fertiliser timing and uniform effluent irrigation, or practising on-off grazing on a wintering pad where urine and dung can be captured and redistributed onto paddocks evenly.

2.1.3 Soil recovery after pugging

Wherever possible, compaction and pugging should be prevented. However, once compaction has occurred, if the soil is left to a natural process, recovery can be slow and compacted conditions may persist for 6 months or more. Where compaction has been caused by intensive grazing over a number of years, the effects can be cumulative.

Natural recovery can be aided by a number of strategies:

- Avoid grazing with heavy stock for as long as practical. Consider using the pugged paddock for silage though this may be rough on machinery. Rolling is sometimes practised to smoothen paddocks, but may cause further compaction
- Undersowing and careful weed control may help to restore the grass/clover sward and protect bare soil from further deterioration
- Summer crops, may be grown, using cultivation to help break up the compacted soil. However, soils damaged by pugging have lower crop yields, and repeated cultivation and cropping of the same paddock further weakens soil structure. Returning the paddock to pasture after the crop will help restore soil structure.

Where natural rejuvenation of structure is very slow, the use of aeration or subsoiling may be considered. Aeration is the use of shallow soil-loosening machines to open the soil. Aeration does not always improve pasture growth, and will only be effective if the soil is moist (but not wet) and if there is good natural or artificial drainage through the lower soil profile.

Aeration is best carried out in spring, though it may result in reduced production when soil dries out in summer, due to pasture damage. Autumn aeration can be effective as long as de-stocking occurs over winter. Results may vary from region to region, due to differing soil structure and climate.

Subsoiling - also known as ripping - is the loosening of the soil below the depth of normal cultivation using a rigid tine instrument. The instrument can be of 'conventional' or 'winged' construction. It is normally operated at depths of 300 to 500 mm.

Figure 2.1-4 shows how subsoiling acts on the soil. When a subsoiler is pulled through the soil, it loosens compacted layers by lifting and cracking them, creating a network of interconnected pores. Many of these pores extend from the depth of loosening up to the soil surface. They can, therefore, act as pathways for root penetration and for transmission of water and air. This increases the effective rooting depth and the amount of water and nutrients available to the crop.

Subsoiling is expensive in terms of power, fuel and labour and should be reserved for paddocks or areas of paddocks where evidence justifies its use. Dig several holes in the paddock to a depth of 500 mm and examine the pit wall carefully to determine the presence, absence and/or extent of a compacted subsoil layer.

Under non-irrigated conditions, increased water uptake after subsoiling can give much higher crop yields.

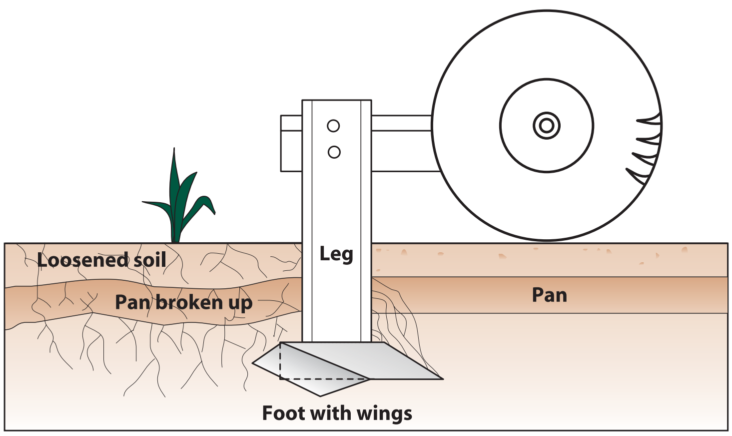
Under fully irrigated conditions, subsoiling responses can be small because with frequent water applications, rooting depth is less important.

Where waterlogging of pasture soils is a persistent problem, drainage of the whole profile should be considered before subsoiling because:

- In wet districts, subsoiling may simply move the zone of waterlogging deeper and result in a soil that is difficult to manage and prone to further compaction
- Subsoiling must be done in appropriate soil conditions to be effective and not to cause damage in the process. In poorly drained soils there is a short time frame in which the soil has suitable moisture content.
- Mole ploughing may be better than subsoiling in heavy, wet soils since the mole drain will take the water off the paddock.

FIGURE 2.1-4

DIAGRAM OF SUBSOILING ACTION



For more information on drainage, refer 2.1.1.4 Drainage.

2.1.3.1 Critical factors for successful subsoiling

Once the requirement for subsoiling has been confirmed, successful subsoiling is dependent on soil moisture, tine depth and tine spacing.

The soil moisture content needs to be in the optimum range. If the soil is too wet, the subsoiler will not lift and crack the soil but will instead tend to create more compaction problems. If the soil is too dry, large blocks of soil will be lifted but not cracked. The best time to subsoil is in spring or autumn when the soil is moist and friable.

When conditions are ideal a small block of soil will crack or crumble when pressed between the fingers and a 'worm' cannot be easily formed (refer to Figure 2.3-1)

The depth of the tines - 'critical depth' -should be correct. Each combination of implement type and soil conditions has a 'critical depth' at which subsoiling is most effective. When a subsoiler is operated at the critical depth, a crescent-shaped pattern of soil disturbance is created. However, if the implement is operated below its critical depth, the amount of soil loosening is much smaller and soil around the passage of the tines can be compacted (refer to Figure 2.1-5).

The depth of subsoiling should be such that crescent-shaped pattern is achieved. This can be gauged by digging a number of holes after test runs.

The tine spacing should be correct. In addition to creating a crescent-shaped loosening, a subsoiler should also produce a uniform pattern of soil disturbance (refer Figure 2.1-6). Where the soil is loosened only around the passage of tines, the tine spacing is too wide.

The optimum interval can be gauged when holes are dug after the test runs. As a rough guide, horizontal tine spacings on conventional subsoilers should not be greater than 1.0 to 1.5 times the operating depth. Spacings of up to 2.0 times the working depth may be suitable for some winged implements.

FIGURE 2.1-5

DIAGRAM OF CORRECT SUBSOILING DEPTH

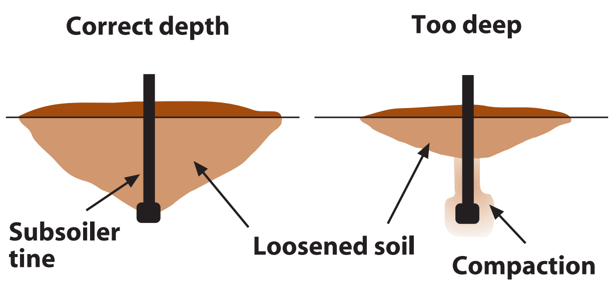
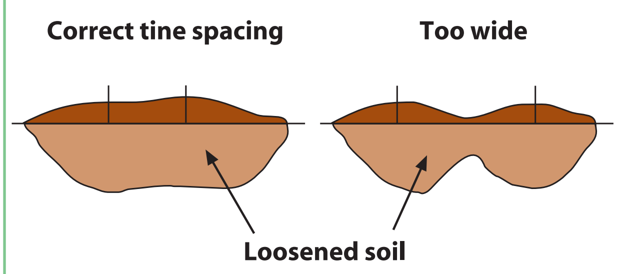


FIGURE 2.1-6

DIAGRAM OF TINE SPACING



2.1.4 Top tips to prevent compaction and pugging

- **Grade paddocks on their susceptibility to compaction and pugging damage; avoid overstocking the most susceptible areas or grazing them in times of heavy rain.**
- **Manage stock to minimise pugging: use on-off grazing or wintering off, move stock sooner in wet conditions and walk stock off paddocks over long pasture.**
- **Do not cultivate when soils are too wet – soil should break easily in the hand at the correct moisture content.**
- **Spell pastures that have been pugged or use them for silage.**
- **Consider drainage or retirement for wet sites.**
- **Use tools like the AgResearch penetrometer to predict the likelihood of pugging damage.**

2.2 EROSION

Erosion refers to all processes by which soil is removed and carried by wind, water, gravity or ice until being deposited as sediment somewhere else.

Erosion is a natural process and many of New Zealand's best soils are deposits of eroded material (e.g. alluvial river terraces or loess-covered downlands).

However, accelerated erosion is a problem if it affects the dairy farming operation through:

- Loss of productive land or topsoil
- Rendering river flats unproductive through siltation
- Destruction of farm structures such as fences, races and crossings
- Loss of nutrients, including fertiliser, with the eroded soil
- Greater cost of drain and culvert cleaning
- Lowering of water quality and more wear and tear on pumping equipment in sediment-laden waterways.

Control of waterway erosion and sediment deposition will often involve several farmers, depending on the length of the waterway. Local farmer groups could be one way of tackling the problem and a means of attracting financial and technical assistance - check with your Regional Council.

2.2.1 Making appropriate land use choices

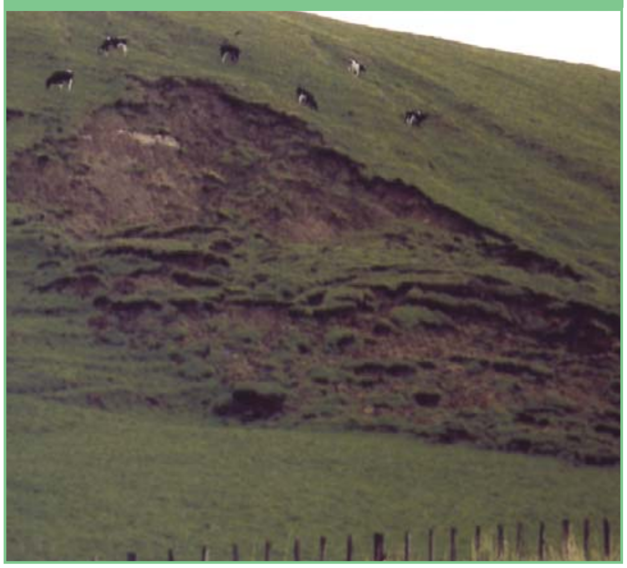
The first preventative step in avoiding erosion is to make appropriate use of each class of land on the property.

The key objective is to separate lower-producing, erosion prone land units from better arable or pastoral land. Many dairy farms have a variety of land contour, and it is a good principle to use the gentler gradient of land more intensively, and to run only young stock or consider retiring land that is too steep for dairying. Inputs of fertiliser and weed control can then be focused on the more productive land where a higher return will be achieved from them. Retired land can be used to grow a forestry crop, or native trees can be planted or allowed to regenerate for aesthetic value, birdlife and land protection.

Some dairy farmers use the rule of thumb that any land on their property that is too steep to have fertiliser spread by truck is retired from dairy grazing. Cultivation should also be avoided on steep slopes. The particular circumstances of each farm will determine the most appropriate land use choices.

FIGURE 2.2-1

EROSION-PRONE LAND THAT COULD BE RETIRED TO PREVENT FURTHER SOIL LOSS



2.2.2 Minimising the depletion of vegetative ground cover

Ground cover protects the soil against wind and rain as it softens the impact of raindrops and traps windblown and water-washed soil.

Wind-blow and gully erosion can occur almost anywhere if ground cover is depleted, even on flat land.

Erosion is especially likely if strong winds or heavy rains follow:

- Cultivation of paddocks when the soil is dry and loose
- Burning of stubble after crop harvest
- Continued grazing of pasture during drought, cold, or wet conditions
- Heavy grazing of pasture.

Light soils with a high silt or sand content are generally more susceptible than loams, heavy clays or peats.

The amount of bare ground is negatively correlated with pasture growth. Research shows that a dense pasture sward:

- Can trap up to 90% of windblown and water-washed soil before it leaves the paddock (on a gentle gradient of land)
- Helps reduce compaction and pugging of wet soil
- Helps reduce weed invasion.

To maintain pasture quality and prevent weed intrusion or rank growth, rapidly growing pastures should be well grazed. Pugging should be avoided as this opens up the sward.

2.2.3 Minimising erosion from cultivated soils

Minimising the amount of tillage on cultivated paddocks will help to retain organic matter that binds soil particles together, making them less prone to erosion (refer to 2.3.2 Minimum tillage and direct drilling).

Windbreaks are also helpful to protect cultivated soils as the trees provide shelter from wind and reduce windblown erosion.

2.2.4 Using trees to improve soil strength

Soil failure by mass movement (i.e. slipping, slumping or flowing of subsoils) can occur on steeper slopes. This is most likely after heavy or prolonged rain.

As clearing native vegetation on steep slopes is one of the fundamental causes of erosion, tree planting or natural regeneration are often the most cost-effective means of erosion prevention and control.

Trees protect the soil by:

- Shielding the topsoil from direct raindrop action and surface water flows
- Binding the soil together with their root systems
- Drying the soil profile.

Other advantages of trees include:

- Providing shelter and shade for stock
- Improving aesthetics and landscape values and increasing property values
- Possible fodder reserves.

For information on planting trees, refer to 4.3 Plantings on dairy farms.

2.2.5 Bank protection

Physical damage to drains and waterways can occur if stock are grazed on banks. Similar damage occurs when stock and vehicle crossings pass through streams, instead of across bridges or culverts (refer to 6.5 Waterway crossings).

Tree planting can also be used along waterways to strengthen banks.

For recommendations on minimising damage to waterways, refer to 4.1.3 Riparian management.

2.2.6 Erosion from tracks and races

Tracks and races can be a significant source of sediment and runoff to streams, especially on farms with a reasonable contour.

Steps to avoid erosion from tracks and races include:

- design and siting of tracks to ensure a gentle gradient and low batters
- cut-offs at regular intervals on slopes so that runoff is directed into grassy areas
- diverting runoff from the track into channels beside the track and/or onto grass or wetland areas
- creating gentle batters with a rough surface that can be regrassed or fenced and planted.

For more detail on design of tracks and races to avoid erosion, refer to 6.3 Road crossings.

2.2.7 Top tips for erosion control

- **Assess suitability of different land types for different land uses and consider retiring steeper areas into a forestry crop or native cover.**
- **Take action if the following are observed: bare soil on slopes or banks, excess dirty run-off down races into waterways, silt entering waterways from pasture or drain discharge.**
- **Manage grazing to avoid opening up the pasture sward.**
- **Plant shelter around paddocks used for cropping to prevent wind-blown erosion.**
- **Use trees to stabilise erosion-prone areas.**

2.3 SOIL PROTECTION UNDER CULTIVATION AND CROPPING

A good soil structure is essential for cropping because of its ability to hold and absorb water while maintaining aerated conditions. Well-structured soils have a high proportion of aggregates or large clusters of particles that are not easily broken down, and larger pore spaces that allow free movement of air and water.

Continuous cultivation and cropping is not common practice on New Zealand dairy farms. However, damage to soil structure may occur when cultivating, cropping or break-feeding a crop on the farm.

Soil structure can be restored under pasture. This restoration is slow but fits in well with the longer pasture phases common on New Zealand dairy farms. This long pastoral phase also serves to increase organic matter levels.

2.3.1 Cultivation

Cultivation should be carried out under correct conditions, using suitable equipment and techniques. To prevent damage to soils under cropping:

- Keep cultivation to a minimum (refer to 2.3.2 Minimum tillage and direct drilling)
- Cultivate only in suitable soil moisture conditions
- Use lighter machinery where possible
- Incorporate crop residues where appropriate to build up organic matter
- Minimise the time that bare soil is exposed to the weather
- Delay final cultivation until ready to plant
- Rip wheel tracks and other compacted areas to ensure good water absorption.

FIGURE 2.3-1

CORRECT SOIL (BOTTOM) AND INCORRECT (TOP) MOISTURE CONDITIONS FOR CULTIVATION

Source: Graham Shepherd

2.3.1.1 Soil moisture

Avoid working the soil when it is wet. The water content is the most critical factor influencing the response of a soil to cultivation.

A hard, dry soil - of whatever texture - has considerable internal strength and may not be easily cultivated. As the soil rewets, its internal strength reduces and less force is required to break it up.

At a point, just before it contains enough water to become malleable, a soil reaches a state when lumps of it break off with minimum force - this is the ideal state for primary cultivation. Try rolling the soil out with the fingers to form a 'worm' around 4 mm thick and 50 mm long (refer to Figure 2.3-1). When the soil cracks before forming a 'worm', conditions are suitable for cultivation.

2.3.1.2 Machinery

Select cultivation implements that minimise structural damage. A good combination might be a disc ripper for primary cultivation, followed by a multi-tine harrow for secondary cultivation (refer to Figure 2.3-2). Rotary cultivators and power harrows cause more damage to soil structure than tined implements and can create plough-pans.

Use lighter equipment where possible to avoid compaction.

Minimise soil compaction by using low ground-pressure machinery, for example low inflation-pressure dual wide tyres or tracked wheels on tractors, and grain harvest bins or trailers with tracks.

Machinery traffic can also be reduced by using wide tillage implements (dual-wheeled heavy tractor needed) and confining vehicles to designated tracks alongside paddocks and 'tram lines' within paddocks. These can later be ripped to address compaction.

Traffic during wet periods should be avoided at harvest as well as during preparation.

FIGURE 2.3-2

MULTI-TINE HARROW AND DISC RIPPER

Source: Vaderstad, NZ Crossboard

Source: Gary Sim, Clark Farming Group

2.3.2 Minimum tillage and direct drilling

The term minimum tillage encompasses reduced tillage, conservation tillage, direct drilling, and no-tillage/zero-tillage. The basic aim is to establish new crops with the least soil disturbance possible. Different options will suit different farms and cropping systems and may include:

- Direct drilling of seed into stubble or pasture
- Spraying followed by direct drilling
- Spraying followed by a reduced number of cultivation passes before sowing
- Reducing the use of conventional ploughs and harrows.

Herbicides have extended the opportunity for applying minimum tillage. Herbicide applied before cultivation allows more rapid breakdown of old vegetation, and can reduce the number of passes with implements required. Desiccation of herbage on the surface makes the cultivation operation easier. Minimum tillage is now rarely used without also applying a herbicide.

Direct drilling is now used by many cropping farmers as an alternative to conventional cultivation, with a number of advantages (refer to Table 2.3-1). However, it will not suit all farming situations.

Even where direct drilling is not employed, the number of passes over a paddock can be minimised by using equipment with multiple rows of tines, rollers and bar crumblers.

If soil moisture conditions are optimum and the plough and harrow are adjusted to suit the soil and the tractor, two-pass cultivation may be all that is required even with conventional equipment (once with the plough and once with the harrow).

Minimum tillage is not just 'not ploughing' – it must be thought of as a whole package, with practices adapted to the situation.

Soil condition is critical for successful crop establishment, and paddocks with compacted soils may not be immediately suitable for direct drilling. Consider the following:

- Soil surface – the planter must be able to achieve consistent seed depth and good seed-to-soil contact – check with your contractor or equipment supplier
- Soil compaction and drainage – shallow compaction may not be an issue for the planter and seedlings, but deep compaction may require aeration or ripping
- Soil fertility – incorporation of fertiliser is not always possible under minimum tillage. Alternatives include broadcasting early, applying starter fertiliser 'down the spout' and side dressing. With direct drilling, there is not the release of N and P which occurs after cultivation due to soil mineralisation. This means N and P starter-fertiliser may be needed to aid seedling growth
- Soil moisture – soil must be moist enough for good germination and dry enough for good aeration.

TABLE 2.3-1

ADVANTAGES AND DISADVANTAGES OF DIRECT DRILLING

Advantages	Disadvantages
• Organic matter is retained, and fertile topsoil remains intact and is not buried by cultivation • Better soil moisture retention • There is less risk of erosion • Soil pores are more stable and continuous from the surface to the subsoil, resulting in more effective aeration, more rapid infiltration and drainage, less runoff and penetration of roots to a greater depth • Soil strength and surface firmness are greater in direct drilled soil, reducing the risk of soil compaction associated with animal or vehicle traffic over wet soils and reducing planting delays due to wet weather • The risk of nitrate leaching is reduced • Earthworm numbers maintained with less physical disturbance and greater soil organic matter content • Cost savings and energy efficiencies can be made. No-tillage systems can reduce tractor hours by 75% and fuel consumption by 67%, and include a total labour saving of 44-70% • Shorter turn-around between crop harvest and re-grassing • Paddocks can be stocked until shortly before sowing, so an extra grazing can often be gained	• Pest and disease problems may increase in undisturbed soil - greater use of pesticides eg. slug bait • It does not allow for lime or fertiliser to be incorporated and nitrogen may be temporarily limited if previous crop residues have not broken down - increased requirement for starter fertiliser • Germination and growth may be poor, especially if soil structure has been degraded, if the surface is uneven, or growing conditions are not ideal • It does not break up previous soil pans or allow levelling • Purchase of no-tillage equipment requires a major capital outlay. The option of contractors can be looked at, with the added benefit of their specialist expertise, but the downside of less flexibility with timing • It entails greater use of herbicides

Minimum tillage systems also require attention to pests, diseases and weeds. Consider:

- Crop rotation – this will minimise the risk of pest and disease transfer. Consider the pest and disease status of the previous crop and risk of transfer to this crop
- Current pest and disease status – Slug damage is often a greater problem with direct drilling. Monitoring close to planting date can help assess the need for chemical controls. Consider also likely changes to the weather e.g. cool, damp weather increasing slug problems
- Fallow period – a 4 - 6 week fallow is recommended to reduce pest and weed competition.

Planting machinery must be set up for the specific conditions of each paddock, and must:

- Handle any crop residues
- Place seed and fertiliser at the correct depth
- Maximise soil contact and coverage
- Avoid smearing or opening of the planting furrow.

Post-planting management includes monitoring pests, diseases and weeds, soil fertility and crop nutrition, and soil moisture (if irrigation is available) and timing of first grazing.

2.3.3 Cropping

Different crops have different effects on the soil structure. The overall effect is dependent on the crop, the degree of cultivation and what is done with crop residues.

2.3.3.1 Crop selection and rotation

The general influence that various crops have on the condition of the soil is outlined in Table 2.3-2.

TABLE 2.3-2

SUMMARY: EFFECTS ON SOIL OF GROWING VARIOUS CROPS

Crop	Organic Matter Benefits	Soil Structure Benefits	Other Benefits	Possible Adverse Effects
Pasture	Very good	Very good	Soil surface protected	Pugging
Autumn cereals	Moderate	Good	Stubble protection	Cultivation damage
Spring cereals	Moderate	Moderate	Stubble protection	Cultivation damage
Maize	Poor	Poor		Cultivation damage
Forage crops	Good	Moderate to poor		Cultivation damage
Fallow and bare	Decline	None or negative	Reduction of weeds, pests and diseases	No drying and cracking of subsoil

Adapted from MAF, 1995

Grass has a well-deserved reputation for maintaining and improving soil organic matter and soil structure. Soil organic matter accumulates under pasture primarily because of the exceptionally dense root system. Plant roots are continually growing and dying, adding organic material to the soil.

The stability of soil aggregates and the porosity of the soil are also increased under pasture because:

- The build-up in organic matter under pasture results in soil aggregates being more strongly bound together. Also, the growth and death of the extensive root system causes the formation of "root channels"
- The growing roots help "enmesh" and bind soil particles together
- Earthworm populations increase rapidly under pasture. Earthworms ingest large amounts of soil below the soil surface. The casts have a high microbial activity and become firmly bound together. Also, the extensive burrowing activity of the large earthworm population creates a network of large pores
- The high water use (transpiration loss) from a growing pasture results in a high intensity of drying and rewetting cycles and thus crack formation.

Maize and sweetcorn are planted at low densities. As a result, much of the soil is effectively fallow and receives little or no organic matter input. The root system is not fibrous and extensive like that of grasses, so organic matter inputs from this source are lower. In many cases, virtually all of the above-ground dry matter is removed for dairy fodder or in the harvested crop. As a result, repeated cropping of the soil with maize can degrade soil structure. Cultivation does not build soil structure, at best it only starts to break up compacted soils. Biological factors (roots, worms, bugs, bacteria and fungi) start restoration of good soil structure.

2.3.3.2 Crop residues

Crop residues (refer Figure 2.3-3) are a valuable source of organic matter which can be incorporated into the soil at cultivation after harvest or grazing. When direct drilling is used, previous crop residues may be baled and removed, burned, or left on the surface.

Residues left on the surface can decrease soil water evaporation, increasing water available to the crop, and protect the soil surface from wind and water erosion.

However, residues may also:

- Depress soil temperatures in the spring and reduce the rate of seedling emergence and plant development
- Block drills and influence seed placement (i.e. depths and spacings) at sowing
- Encourage high slug populations that may eat seedlings, increasing the need for agrichemical use
- Contribute to disease carry-over between crops, increasing the need for agrichemical use.

FIGURE 2.3-3

MAIZE CROP RESIDUES

Crop residues that contain little N (e.g. maize) will help reduce the amount of nitrate leached if they are mixed into the soil in autumn and the soil is re-sown to pasture or a cover crop.

Crop residues that contain a lot of N (e.g. vegetables such as turnips) can release N quickly. Do not mix such residues into the soil until just before the next crop or pasture is sown.

The benefits and disadvantages of different residue management options should be assessed to make a sound decision for each individual situation.

2.3.4 Pasture renovation

Pastures may require renovation and regrassing for many reasons but the aim should be to achieve a vigorous pasture sward with minimal negative impact on the environment.

Poor pasture performance may be due to:

- Soil pH or fertility problems
- Weed problems
- Drainage problems
- The presence of pasture pests such as porina or grass grub.

Regrassing may not be the solution. Regrassing is costly and intensive in terms of labour, energy and agrichemicals. Find out why the pasture is not performing and use the appropriate management tool to improve the situation (refer to Table 2.3-3).

TABLE 2.3-3

REASONS FOR AND SOLUTIONS TO POOR PERFORMING PASTURES

Reason	Solution
• Insect or weed invasion	• Graze carefully, control pests and weeds
• Inadequate fertiliser	• Soil test and correct deficiencies
• Poor pasture utilisation	• Increase utilisation (e.g. subdivide the paddock)
• Damage from pugging or vehicles	• Spell the area from grazing. Reseed or cultivate if serious. Consider drainage
• Lack of productive pasture species	• Renovate. Use banded or blanket herbicide
• Poor pasture species (e.g. 25% kikuyu)	• Renew. Use cultivation or direct drilling

AgResearch, 1993; Dairying Research Corporation Ltd

Other factors such as the physical nature of the land and the availability of machinery also influence the approach (refer to Table 2.3-4).

TABLE 2.3-4

CONDITIONS THAT LIMIT THE CHOICE OF REGRASSING TECHNIQUE	
Condition	**Solution**
• Too steep for machinery	• Broadcast seed
• Risk of erosion	• Direct drill seed
• Rocky or stony soils	• Broadcast or direct drill seed
• Rough or tracked surface	• Cultivate and level
• Dominant weed grasses (e.g. kikuyu)	• Blanket herbicide spray and direct drill
• Heavy clay soils	• Avoid cultivation – direct drill with coulters

AgResearch, 1993; Dairying Research Corporation Ltd

2.3.4.1 Regrassing with direct drilling

It has been estimated that in some regions of New Zealand, 90% of pasture renovation on cultivable land is now being done without tillage.

Pastures dominated by unsown grasses (eg. paspalum, fog, browntop, fescue) or weeds can be sprayed or double sprayed before drilling to eliminate competition between new seedlings and established plants. Standard practice is to:

- Hard graze the pasture to between 30 and 60 mm to remove pasture and trash
- Allow pasture to freshen. Allow 7 to 21 days or 50 to 100 mm growth
- Blanket spray with a glyphosate herbicide, closely following recommended spraying rates; (applying a second spray after six weeks to eliminate dormant seed if necessary)
- Graze 5 to 7 days after spraying - just before the pasture browns off
- Drill seed.

2.3.4.2 Pasture management after sowing

When plants 'snap off' and do not 'pull out' when plucked by hand, allow a first grazing with calves. This will be about six weeks after emergence. Frequent, light grazings during the first winter and spring will encourage tillering.

Light applications of N fertiliser (eg. 15 kg of N per ha) after the initial grazings will encourage seedling establishment.

Do not:

- Pug in winter
- Overgraze in summer
- Cut for silage or hay in the first spring after sowing.

2.3.4.3 Cost effectiveness of various regrassing techniques

There are three main methods for regrassing - cultivation, spray and direct drill and undersowing. Cultivation is likely to be the most expensive.

Spray with direct drilling gives cost effective results as the old grasses and weed species can be well controlled. This method can be cheaper than cultivation. A second spray may be needed before drilling to eliminate competition from old grasses.

While undersowing is the cheapest method results are variable, requiring farmer experience, exact timing, correctly adjusted machinery and precise conditions for seedling establishment.

2.3.4.4 Novel endophyte pasture establishment

Endophytes are a naturally-occurring fungus that protect ryegrass plants from insect attack (e.g. black beetles and Argentine stem weevil). However, they can also cause animal health problems, including ryegrass staggers.

Novel endophyte ryegrass varieties contain naturally occurring endophytes selected to maximise protection from insects and minimise animal health problems. A range of novel endophyte ryegrasses are now available (see Dexcel FarmFact 5-25).

The benefits of these varieties will only be felt if there is minimal contamination from wild-type endophytes. This may be from:

- Surviving endophyte-infected ryegrass plants
- Natural reseeding from surface seed
- Reintroduction of seed in hay and cow dung.

Therefore, when establishing novel endophyte pastures:

- Preferably grow a crop over summer first to minimise natural reseeding and peristence – avoid growing hay in the paddock prior to sowing
- Spray and cultivate to kill old ryegrass plants and bury surface seed, or double spray with a fallow between (apply herbicide in late summer and again after the autumn rain has encouraged seedling emergence)
- Do not under-sow into existing pasture
- Do not feed out hay cut from old species paddocks onto the new paddocks

2.3.5 Managing peat soils

Peat soils are particularly sensitive to continuous cultivation as this accelerates the rate of shrinkage to more than twice that of peat soil under pasture. However, cultivation of peat soils is often required to increase aeration and incorporate lime to reduce natural acidity. Cultivation often needs to be repeated over time as the cultivated peat decomposes and becomes too shallow to sustain pasture. This may be signalled by the appearance of dry knobs in the soil. The knobs become more widespread until the paddock has to be cultivated, levelled or shaped and regrassed to become productive again. As peat mineralises over time, the interval between pasture renewal can be increased. Careful grazing, avoiding pugging or bare pasture and retaining good pasture residuals can also help extend the life of pastures.

No-till methods of pasture renewal are recommended for peat soils where possible to reduce the impact of cultivation on peat shrinkage. During initial development of soils and where cultivation is required to incorporate lime, cultivation should be to a depth of around 200-250mm to provide an optimum rooting depth for pastures and crops. If cultivation is deep enough at the outset, and lime is incorporated to a good depth, it is likely that vigorous pasture will establish and cultivation intervals can be extended.

Cultivation intervals can generally be extended out after two pasture renewals, if coupled with good water table management (refer to 4.1.4.6 Managing water levels in peat soils) and careful grazing (refer to 2.5 Pasture management). Shrinkage of the peat will continue, although at a slower rate. Soil tests can be used to determine pH and lime requirements on an ongoing basis.

2.3.6 Top tips for soil protection under cultivation and cropping

- **Avoid continuous cropping - incorporate a pasture phase to rebuild soil structure.**
- **Use good grazing management to extend pasture life and avoid the need for costly regrassing.**
- **Sow new pastures in paddocks that can be well managed - renovate pastures in early autumn when conditions are best. Use frequent light grazings to help establishment.**
- **Use minimum tillage or direct drilling where appropriate to protect soil from exposure and vehicle compaction.**
- **Where cultivation is used, incorporate crop residues or other organic matter such as compost or effluent solids to rebuild soil organic matter.**
- **Cultivate only in suitable soil conditions and minimise the number of passes over a paddock.**

2.4 BIOLOGICAL MAINTENANCE OF SOIL

Soil contains countless living organisms ranging from bacteria, fungi and protozoa to earthworms and beetles. These organisms play a major part in maintaining natural soil processes that sustain the fertility of the soil.

There are also soil additions available in the form of preparations or 'starters' that aim to increase biological activity by introducing beneficial soil micro-organisms into compost or directly to the soil. However, introduced organisms will not thrive unless conditions are optimum for soil life in terms of aeration, availability of organic matter and moisture. When these conditions exist, natural build-up of soil micro-organisms and earthworms will occur.

2.4.1 Optimum soil structure and aeration

For maximum biological activity in the soil, soil structure must be maintained so that aeration is optimal at around 50% of the total soil volume. This means avoiding compaction and pugging of the soil through overstocking, overgrazing or cultivating in wet conditions. In waterlogged soils, drainage will improve aeration.

2.4.2 Organic matter

The powerhouse for biological activity is the organic matter present in the soil. Systems under continuous pasture, where organic matter is 'recycled' by grazing animals depositing dung generally have high levels of biological activity compared to cultivated cropping systems. Clovers also make additional nutrients available and the grass-clover root systems create ideal habitat for soil micro-organisms.

Land application of dairy effluent provides a valuable addition of organic matter to pastures. Farmers often report a visible improvement in earthworm numbers on areas being irrigated with effluent. However, application of effluent at too great a depth or frequency can create a 'seal' over the soil surface, and produce anaerobic conditions.

Do the following to maximise organic matter content of the soil:

- Irrigate dairy effluent according to best practice to increase food supply and soil moisture content in the summer (refer to the Dairying and the Environment Committee manual on Managing Farm Dairy Effluent)
- Incorporate composted materials or well-composted animal sludge and semi-solids into the soil
- Incorporate crop residues into the soil
- Use shallow cultivation and minimum tillage techniques, as opposed to full cultivation.

2.4.3 Chemical residues

Soil organisms are sensitive to certain chemicals and contaminants that are applied to soils. These include pesticides designed to control particular pests, but which can also affect a variety of organisms.

Avoid pesticide application where possible, and where using pesticides, choose carefully and follow the instructions on the label.

For further information on the management of pesticides and herbicides, and their residues, refer to 7.1 Agrichemical use.

2.4.4 Maintaining earthworm numbers

A high level of earthworm activity in soils is an advantage as earthworms improve soil fertility and soil drainage characteristics. Reduce physical damage to earthworms due to pasture pugging and cultivation and help maintain optimum conditions for them. This will also improve the general biological activity of the soil, resulting in an increased nutrient supply to pasture and crops and an improvement of the soil structure.

Maintaining liming will help ensure that soils do not become overly acidic and unsuitable for earthworms.

2.4.5 Top tips for maintaining soil life

- **Build organic matter in the soil through land application of effluent, and addition of compost, crop residues or sludge during cultivation.**
- **Avoid compaction or pugging that can damage soil structure, reducing aeration and infiltration.**
- **Use shallow cultivation and minimum tillage techniques.**
- **Minimise pesticide use, choose pesticides carefully and follow instructions on the label.**
- **Use lime to avoid soils becoming too acidic for earthworms and other beneficial soil life.**

2.5 PASTURE MANAGEMENT

The basis of New Zealand's cost-effective grazing system is the grass-legume pasture. Traditionally this has been a ryegrass-clover mix, but there are other species used for certain situations, including chicory, tall fescue, brome and phalaris for dry conditions. Specific cultivars of ryegrass and clover have also been bred for low fertility areas, acid soils and pest or disease resistance.

For successful pasture establishment and continued development, it is important to provide a favourable environment for seedling germination and the rapid growth of grasses and clovers.

On dairy farms, pasture growth must be maintained throughout the milking season to meet stock requirements, and maximise Dairy Operating Profit. The main aims are to:

- Match total pasture growth to stock requirements
- Match timing of feed supply and demand (relating to calving date and spread)
- To offer the herd high quality feed and maintain cow intakes. This will avoid excessive weight loss in early lactation. High quality feed will encourage each cow to eat more and produce a higher peak level
- To reduce competition from other plants, whether older pastoral plants or weeds
- To minimise the effects of pugging damage in winter and hard grazing in summer
- To minimise competition between grasses and clovers, (e.g. not shading clover).

It is a fine balance, as pasture intake must be carefully controlled over autumn and winter, and the spring flush adequately utilised or stored for periods of high demand. Pasture growth may be maintained through a combination of correct stocking, good grazing management and weed control.

A feed budget may be prepared by estimating the herd's requirements and matching this against probable pasture production. Monitoring is then required to see whether pasture growth is tracking as per the budget. Growth may be monitored by eye, by sampling, or by equipment such as the 'rising plate', pasture cage or electronic pasture probe or an ATV-mounted pasture meter.

Animal growth rates and production can also be monitored to assist in management. Automatic recording technology is now available for both liveweight and milk production. This sort of information will help the farmer spot health problems, ensure target weights are achieved for mating and calving, and inform the breeding programme.

Maintaining feed quality is a key focus for research and extension, and can also affect nutrient losses from the farm system. Seek the latest information from Dexcel, your farm advisor or visit www.envirodirect.co.nz .

2.5.1 Stocking rates

Stocking rate has traditionally been defined as 'cows per hectare'. It is a measure that should be carefully used in context of the farm in question. The helpfulness of cross-farm and cross-region comparisons is weakened by the following:

- 'Cows' are not uniform. They have varying Production Worths and varying weights.
- 'Hectares' are not uniform. Land from one region to the next does not necessarily have similar pasture production potential.
- The 'environment' is not uniform. Some regions, soils and catchments are more sensitive than others.

For example, 3 cows per hectare may be considered 'high stocking' on a farm that has infertile soils and poor climate and is surrounded by sensitive waterways, whereas 3 cows per hectare may be considered 'low stocking' where the reverse situation exists.

2.5.1.1 Deciding on a stocking rate

Low stocking can result in lower overall profitability. High stocking can put more pressure on the overall farm system and the environment.

The best stocking rate involves examining the uniqueness of the individual farm system. Match stocking rate to pasture production, inputs, available resources, and environmental effects.

Low stocking may have benefits because:

- It can protect sensitive soils from compaction and pugging
- It reduces labour demand
- The remaining stock are better fed. This could reduce per cow costs (i.e. animal health, electricity, farm dairy costs etc), particularly where high breeding worth (BW) cows are able to perform more to the potential that has been bred into them
- The environment may be adversely affected by higher stocking rates producing more runoff and leaching.

If farm inputs remain constant, a farmer choosing to milk lower numbers of cows would need to see production per cow increase to make that choice pay. Otherwise a decrease in stocking rate may reduce financial benefits from lower costs if the payout rises.

2.5.1.2 Comparative stocking rates

As dairy farm systems have evolved, the use of 'cows per hectare' has become less useful as a measure of stocking rate.

The measure of Comparative Stocking Rate (CSR) is a calculation that makes a more objective comparison between farm systems by indicating the match between feed demand and supply.

CSR is defined as kg liveweight per tonne of dry matter and the optimum level for per cow production, per hectare production and profitability is between 80 and 90.

To calculate it accurately, farm-specific information is needed regarding annual pasture production, quantities of imported feed and cow liveweight.

Total liveweight is calculated according to the following:

Total liveweight/ha = total number of cows milked at peak / effective area (ha) X average cow liveweight (kg).

Dry matter available is calculated according to the following:

Total dry matter available (tDM/ha) = Total pasture grown on milking area (kgDM/ha) + Total imported feed divided by effective farm area (kgDM/ha) / 1000 kg/t.

An adjustment is made for feed used by young stock by calculating:

Feed used by calves = Number of calves X 3.5kgDM/day X days / farm area grazed

Feed used by heifers = Number of heifers X 6.0 kg DM/day X days / farm area grazed

Add these two figures (calves and heifers) and divide by 1000 to give tDM/ha used.

Net feed is given by:

Net feed for dairy production (tDM/ha) = Total dry matter available (tDM/ha) – Feed used by young stock (tDM/ha)

Comparative Stocking Rate is then calculated from the above as follows:

CSR (kgLWT/tDM) = Total liveweight/ha (kgLWT/ha) / Net feed for dairy production (tDM/ha).

2.5.2 Grazing

Good grazing practices at correct stocking rates will efficiently utilise pasture grown - whether that be through grazing or through the production of supplements.

To prevent weed intrusion or rank growth, pastures should be regularly grazed (refer Table 2.5-1). High stocking densities or break feeding can be used as management tools to control weeds, but it is also important to avoid opening up pasture through pugging so as to maintain a dense grass sward.

Table 2.5-1 lists general principles pertaining to round length with respect to each season However, as each property is different, cow demand and the management of supplements also need to be considered.

TABLE 2.5-1

SEASONAL PASTURE MANAGEMENT - GENERAL PRINCIPLES		
Season	**Round length**	**Focus**
Winter and early spring	60 to 100 days	Slow round after calving to build up feed ahead of the herd. Prevents feed shortages and stress during later rounds preceding reproductive cycling
Late spring	14 to 16 days	Very fast round so that rapidly growing pasture is utilised and controlled
Summer	20 to 25 days	Fast round to clean up pasture, consume rank growth and maintain pasture quality
Autumn	30 to 40 days	Slowing round to build up feed in front of the herd before spring calving

Note 1: 'Round Length' is the number of days it would take for the herd to return to the same paddock having grazed the property. It is calculated on the basis of the proportion of paddocks on the farm grazed each day.

Note 2: The table focuses on pasture growth and pasture quality. Cow demand and the management of supplements also need to be considered.

Farm subdivision with fencing is important to control pasture uptake and maintain the pasture sward. A combination of permanent and electric fencing is required.

When direct drilling new pastures, graze hard before drilling. Hard grazing will reduce the competition between developing seedlings and older pasture plants.

2.5.2.1 Fertiliser, pasture quality and clover

When subject to N fertiliser application, paddocks will require more regular grazing to maintain pasture quality. Otherwise, pasture will become too long and clover will be shaded out, reducing the clover content of the pasture (refer to 3.3 Nitrogen fertiliser).

2.5.2.2 Turf pulling

Turf pulling commonly occurs where the soil structure has been physically damaged.

Pasture should not be grazed when soils are very wet, as pugging will occur. Compaction in the top few centimetres during grazing may seal the soil and the situation will become worse with successive grazings during wet periods (refer to 2.1 Compaction and pugging). Grass grub may also result in a turf-pulling problem.

2.5.2.3 Grazing near waterways

Stock exclusion from waterways is one of the targets of the Dairying and Clean Streams Accord which is also part of the Dairy Industry Strategy for Sustainable Environmental Management.

It is important to protect areas near streams from erosion or pugging while being grazed. This can be a problem particularly where soils are permanently or seasonally saturated and then intensively grazed in rotational stocking systems.

In winter, use electric fencing to create a filter strip of long grass between grazed areas and streams, and graze areas beside waterways less intensively (refer to 4.1.5.2 Grazing paddocks near waterways).

2.5.2.4 Utilising extra production from on-off grazing

Where a stand-off facility is added to the farm operation, surplus pasture may be grown in spring due to improved soil and pasture condition with on-off grazing. To make the most of the investment in the stand-off facility, management changes may be made:

- Increase stocking rate – ensure comparative stocking rate is between 80-90 kg LW/tDM
- Calve earlier
- Be more vigilant in identifying pasture surpluses and make more silage earlier, of higher quality
- Reduce supplement feeding earlier in the season
- Keep pasture residuals at target levels – stop feeding supplement before residuals increase beyond target.

2.5.3 Weed and pasture pest control

Weeds are 'pest plants'. Such plants are a problem if they are poisonous, taint milk or compete with pastoral or native plants. Pasture pests include grass grubs, porina larvae, black beetle, army worm and clover root weevil.

Weeds that pose the biggest problem on dairy farms in terms of milk production include ragwort, gorse, thistles (e.g. Californian, scotch, nodding, winged, variegated) and buttercup species. Dairy farmers are generally aware of the costs to production that weeds impose, and usually take steps to control them. Particular care is needed when controlling pasture weeds by spraying as many sprays will also damage clover. Wherever possible, pasture weeds should be controlled by good grazing management and spot spraying or 'wands' or 'weed wipers' to avoid this. Consider biological control for long term, low-cost treatment.

Some weed species also pose problems to the environment outside the grazed pasture areas of the farm (refer to 4.3.6.1 Weed control in retired or planted areas). Planting densely in these retired corners of the farm will help reduce weed populations over time, and may be more cost-effective than keeping 'difficult' corners of the farm in pasture. Advice can be sought from Regional Councils about control of both pasture and environmental weeds.

2.5.3.1 Methods of weed control

Weeds are spread as seeds (i.e. via water, wind, birds, machinery, animals and hay, and by using uncertified grass seed), rhizomes or stolons. Knowledge of how a weed spreads often determines the appropriate management strategy.

Weeds are controlled by four basic means. A combination of two or more of these methods is often the most successful:

1. Pasture management. A dense healthy sward is the best defence against weeds in pastures. Avoid pugging, overgrazing or insect damage to help maintain a tight sward and keep weed seeds from germinating. Good drainage, the use of appropriate pasture cultivars, and optimum soil fertility and pH will also help. To prevent weed intrusion, pastures should be regularly grazed (refer 2.5.2 Grazing).
2. Agrichemical use. Herbicides are either selective or non-selective. Some kill by contact, some kill by using the plant's transportation system, and others are synthetic hormones that distort and kill the plant. Chemicals come in various forms including sprays that 'wipe on', sprays that 'paint on', or granules. For more details on using agrichemicals refer to 7.1 Agrichemical use.
3. Physical damage or removal. Weeds can be controlled by cutting, digging, 'chipping', pulling by hand, mowing, crushing and cultivation.
4. Biological control. This is most appropriate where alternative control methods are not physically or economically possible, or would cause unacceptable damage. Biological control involves using insects or other organisms (e.g. diseases, animals such as goats) to control weeds. The insect or organism is known as a 'biological control agent'. The aim is to restore the natural balance between a weed and the environment by introducing an agent that attacks the weed in its native country. The agent damages only the weed, something that is difficult to do through the use of agrichemicals or by physical means. Total weed control is not possible with this method, as agents need some surviving weeds to live on. However, a successful biological control programme reduces the number of weeds to an economic level. Biological control programmes are initially slow and expensive, however, once in place, there are low ongoing costs. Table 2.5-2 lists agents available for the control of weeds of interest to dairy farmers.

TABLE 2.5-2

AGENTS USED FOR THE BIOLOGICAL CONTROL OF PASTORAL WEEDS

Weed	Control agent	Release procedure (minimum numbers)
Nodding thistle	Receptacle weevil Gall fly Crown weevil	Insect is widespread. Redistribution is unnecessary In Nov - Jan, release 800 flies when green flowerheads are plentiful In Dec - Feb, release 300 weevils. In Mar-Jun, release 200 weevils
Californian thistle	Leaf beetle Flea beetle	In Nov - Jan, release 400 beetles once thistles appear above ground In Nov - Jan, release 400 beetles once thistles appear above ground
Ragwort	Flea beetle Cinnabar moth Ragwort crown borer Ragwort plume moth	In Mar - May, release 300 beetles in to rosettes In Sep - Oct, release 100 moths. In Nov - Jan, release 2000 caterpillars Under investigation - See MAF website for details www.maf.govt.nz
Gorse	Spider moth Thrips Soft shoot moth Pod moth	In Oct - Mar, release colonies of 1000 adults In Oct - Mar, release 300 thrips In Sep - Oct, release 100 moths. In Nov - Dec, release 1000 caterpillars on new growth In Oct - Nov or Feb - Mar, release 100 moths when bushes are in full flower
Broom	Seed beetle Physllid Twigminer	In Oct - Nov, release 1000 beetles when bushes are in flower and green pods are forming In Nov - Dec, release 1000 adults onto new growth This agent is widespread. If further releases are required release 1000 moths from Dec - Mar

Note: The release of these biological agents should be carried out through co-operative programmes with Regional Councils, Department of Conservation, Landcorp Farming Limited or forestry companies. It is advisable to check with local authorities as to effectiveness and availability in your area.

Landcare Research New Zealand Ltd, 1995

2.5.3.2 Preventing weed spread

To prevent weeds from spreading into other areas, allow only clean machinery onto your property. Inspect the machinery yourself if you are concerned.

Use only seed that is certified as weed-free or certified low in weeds. Many pest plants have been introduced into areas by using 'bush-burn', uncertified seed.

Be aware of what is growing in your garden. Old farmhouse gardens often contain plants originally planted for their beauty and now considered to be pest plants. Weeds of environmental significance vary between regions and what is a serious pest in one region may be a benign garden plant in another. Seek advice from your Regional Council about the control status of plant pest species.

2.5.3.3 Control of pasture pests

Grass grub is a native insect that has adapted well to improved pasture habitat. It is common in many pasture plants where the larvae attack the roots. Susceptible pasture species include clover and ryegrass, while resistant species include lucerne and tall fescue. Grass grubs are often present in numbers too low to cause economic damage. Where control is required, options include cultivation in spring, mob stocking in late autumn-early winter, and insecticide sprays.

Porina is a caterpillar found in the North Island. It lives in underground tunnels and comes out at night to eat plants at ground level, creating bare patches in the sward. Porina can be controlled by mob stocking and insecticides.

Clover root weevil is a small, plump, crescent-shaped larva with a creamy coloured body, no legs and a tan head. The weevil ranges from 1-6 mm long and feeds on clover roots, nodules and stolons. It can have a high impact initially, and then tends to reach equilibrium. Controls are under investigation at present.

Other major pasture pests include black beetle, black field cricket and argentine stem weevil. The development of ryegrasses containing novel endophytes is aimed at deterring pests like black beetle and argentine stem weevil while reducing the incidence of ryegrass staggers caused by wild endophytes (a naturally occuring fungus).

2.5.4 Top tips for pasture management

- **Match stocking rate to pasture production, inputs, available resources, and environmental effects.**
- **Low conception rates, regular deaths or high veterinary expenses may indicate over-stocking affecting animal health.**
- **Soil compaction or excessive surface runoff may also indicate over-stocking affecting the environment.**
- **Do regular feed monitoring and feed budgets. Regularly assess condition scores and liveweights of the herd.**
- **To obtain consistent high producing pastures, recognise and control the spring surplus, while utilising feed carefully over winter and dry periods in summer.**
- **Allow only clean machinery on to your property and use only seed that is certified as weed-free.**
- **Familiarise yourself with local problem weeds so that you can recognise them and take appropriate action.**
- **Maintain a dense healthy pasture sward as the best defence against weed invasion. Avoid opening up pasture through pugging and pasture damage. Control weeds through regular, thorough grazing wherever possible.**

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