WET WEATHER MANAGEMENT - MANAGING SOIL TO PROMOTE MAXIMUM PRODUCTION AND MINIMAL DAMAGE

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Summary

Intensive dairy cattle grazing on wet soil can have a negative effect on soil physical quality and consequently pasture production. A soil in good physical health can adequately transport and store water and nutrients while physically supporting growing plants and maintain an active biological community. Soil compaction and pugging however decreases a soil's physical health, damages the pasture sward and places limitations on some of the important functions described above, therefore resulting in potential decreases in forage yield and a greater occurrence of surface runoff generation. A soil that has been compacted will have decreased water storage and drainage capability and is likely to contribute to off-site pollution to a great extent due to the loss of nutrients. Furthermore, the exchange of oxygen with the atmosphere, which is essential for soil biological functioning, becomes limited. When it comes to managing soil treading damage; prevention is better than the cure. With soil wetness being the greatest determining factor, the key grazing management options are to decrease either stocking intensity or the time on the paddock. Decreasing time spent on the paddock requires the use of off grazing facilities. The longer the time-off the grass required, the more sophisticated the standoff facility will have to be with regards to effluent management and animal comfort.

Compaction vs. pugging damage

From early spring, soils tend to have high moisture content i.e. at or near field capacity and therefore are prone to animal treading damage. During early lactation (spring), cows, that

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are commonly rotationally grazed on pastures, pose a risk to soils through their effect on soil structure. Treading damage occurs in two forms: pugging and compaction. Soil pugging involves the deformation and remoulding of soil when animal weight exceeds a soil's bearing capacity resulting in an undulation of the soil surface. Pugging takes place when soils are typically very wet and air pores likely to be fill of water. In comparison, soil compaction results in a reduction or compression of soil pore (air) space, and can occur at lower soil moisture content i.e. on moist rather than wet soils. With increasing soil moisture the potential for soil compaction decreases and the risk of soil pugging increases (Figure 1 & 2). Soil compaction can occur together with soil pugging, particularly under cattle hooves. Although both pugging and compaction have a negative effect on pasture growth, short-term damage to the pasture sward is often evident under pugging while compaction can decrease plant growth potential in the long term.

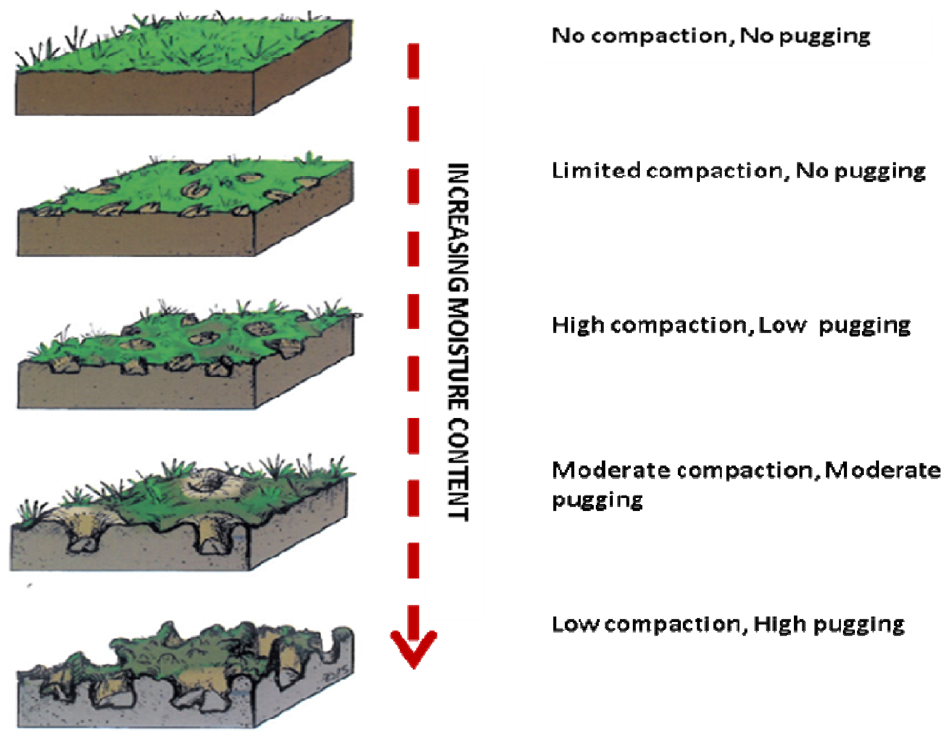

Figure 1. Illustration of soil damage with increasing soil wetness (from Betteridge et al. 2003)

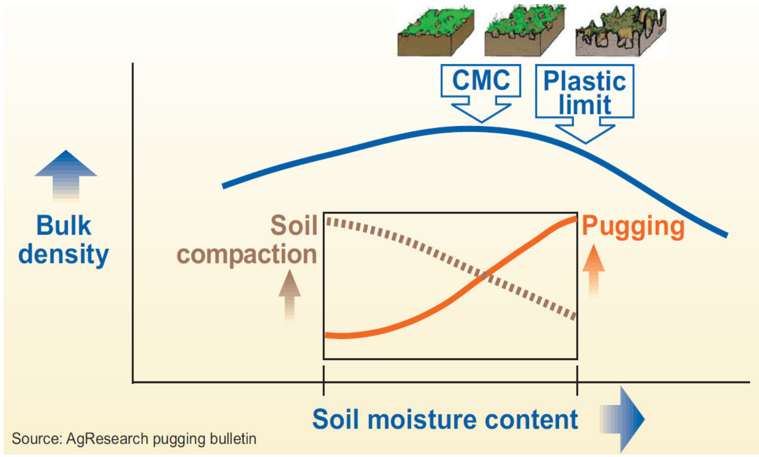

Figure 2. The relationship between bulk density and soil moisture. CMC = critical moisture content where greatest level of compaction is achievable (adapted from Wiedenhoeft 2006)

Factors influencing soil damage

The extent of soil damage under livestock pastoral grazing is dependent on five critical factors:

- Soil susceptibility to damage,
- Soil wetness,
- Livestock loading (weight/hoof contact area),
- Grazing intensity (animals/ha) and duration (time on soil),
- Vegetative cover

Grazing duration and intensity can have a large effect on the extent of soil pugging and damage during a single grazing event. These two factors can be controlled by applying appropriate stock management at times of soil treading risk. The treading effect of an animal is also related to its mass, hoof area and whether it is on the move or stationary. One-off, severe cattle grazing events tend to result in extreme pugging that causes severe damage to the pasture sward and possible lowering of pasture production in the short term. In comparison, long term compaction damage is often a cumulative effect of livestock loading on soils during times when moisture conditions allow for soil compaction.

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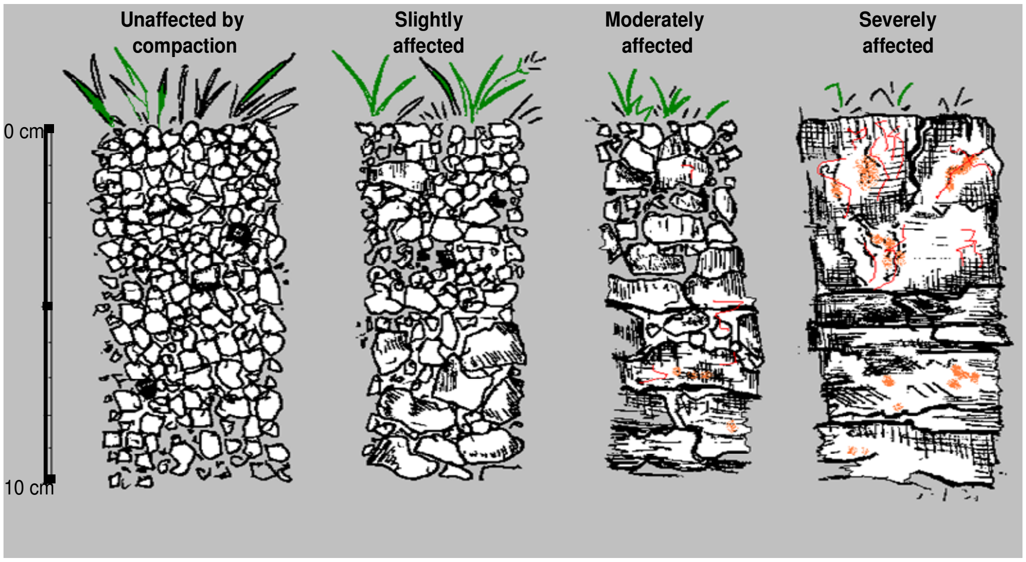
The properties of a soil influence their ability to resist the forces of soil compaction. Soil texture and mineralogy influences the way in which particles align with one another, fine grained soil such as clay loams for instance contain smaller particles than coarse grained sandy soils and therefore pack tightly leaving smaller pore spaces. The clay content and clay mineralogy also influence aspects such as drainage, and the cohesion strength between particles when wet. Such characteristics influence the time that soils remain wet and therefore poorly drained soils with high clay content tend to be more prone to damage from livestock grazing. Soil organic matter increases soil aggregate strength and stability adding greater internal friction and therefore helping withhold the external forces of soil treading. The influence of vegetative cover within a typical ryegrass and white clover pasture plays a small part on minimizing the impact of soil compaction. Some protection is provided by the pasture root mass that promotes aggregate formation, and therefore improve structural stability and pore space.

Effect of soil damage

Soil macroporosity describes the percentage of air spaces within soils that are greater than 0.03 mm, while microporosity describes those less than 0.03 mm. Macroporosity reflects the degree of soil aggregation and therefore is often used as an indicator of soil physical health.

The degradation of soil structure, in particular the loss of macroporosity, as a result of soil compaction, has been shown to have a negative effect on pasture production due to decreased air and water transmission and root growth development (Figure 3). A linear relationship has been defined between soil macroporosity and spring pasture production potential over a range of different New Zealand soil types and is presented in Figure 4. In summary a unit increase in macroporosity was associated with a 1.8% increase in spring relative pasture yield. Generally it is advisable to maintain soil macroporosity above 10% in order to maintain soil processes that are beneficial to pasture production. Early lactation (spring time) is a critical period for soil damage on New Zealand dairy farms due to high soil moisture typical during this period.

The rate by which water moves through soil is commonly described by the infiltration rate. When soil structure deteriorates through the action of grazing animals that smear or indent the soil surface during wet conditions, fine textured sediments may block surface macropores thereby reducing infiltration rate considerably. An effect of decreasing soil infiltration and drainage capability is an increase in overland flow generation resulting in a greater loss of contaminates to surface water such as phosphorus, sediment and faecal microbes.



Topsoil is loose and crumbles easily into small, granular aggregates

Abundant roots throughout topsoil

Worms are common

Upper part of topsoil is loose

Some larger, firmer aggregates between 10 to 15 cm

Roots do not commonly penetrate firmer aggregates

Larger, firmer aggregates more common. Sometimes have a horizontal platy appearance.

Roots grow around rather than through aggregates

Reddish stains along some root channels

Lumpy, irregular surface

Aggregates are coarse or absent

Few roots below 5 cm

Reddish stains along root channels. Soil often greyish in colour and may have an unpleasant smell when wet.

Few worms present.

Figure 3. Illustration of soil damage with increasing soil compaction (adapted from Betteridge et al. 2003)

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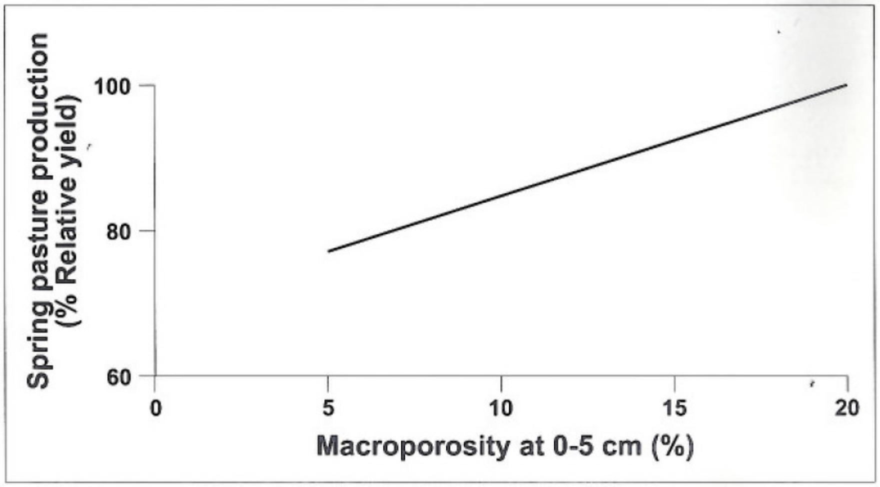

Figure 4. Relationship between soil macroporosity and pasture yield (from Betteridge et al. 2003)

Repairing soil damage

As soil is a living ecosystem it has a natural ability to repair itself and recover from soil compaction damage. However, natural recovery of the soil's structure usually requires a period of rest from physical pressures such as grazing. A number of soil processes enhance soil recovery including wetting and drying cycles, freeze-thaw processes, earthworm activity and root development and decay. Following spring compaction, natural soil recovery takes place over summer and autumn months as soils go through frequent wetting and drying cycles that promote aggregation. Although less evident aggregation of soils may occur during winter if not grazed by cattle and some degree of soil drying accompanies typically wet conditions.

The effects of soil compaction can also be repaired by the use of mechanical loosening equipment, commonly known as 'subsoilers' or 'aerators'. Mechanical loosening typically aerates soil and breaks up compaction pans by pulling through a number of tines to a depth of approximately 25-30 cm. For mechanical aeration to be effective however the soil condition needs to be moist enough to reduce friction and allow an even loosening to the desired depth. If the soil is too wet the physical pressure on aggregates can encourage smearing of the soil and achieve limited loosening benefit. Previous research has shown considerable soil physical improvement following mechanical loosening of compact soils, however there are still uncertainties regarding the long term effectiveness of a loosening event, especially where no subsequent change in land management is made since the initial soil compaction. Most studies for instance have demonstrated that little evidence of the soil loosening remained after a 2 to 3 year period (under on-going grazing).

If soil damage has resulted from a single severe grazing event then consideration should be given to cultivating this paddock and regrassing it as part of a pasture renewal programme or sowing into a forage crop for animal feed supply. Where only moderate damage has occurred then consideration should be given to allowing a period of natural recovery by limiting pasture grazing pressure for a few months i.e. lower weight animals or decreased stock grazing times. Alternatively the pasture could be under-sown where bare patches are prevalent. Where soil is suffering the effects of long term compaction (i.e. macroporosity < 10%) then consideration should be made to mechanically aerating pastures. However subsequent management on the aerated soil (decreased grazing pressure) will be required to prevent rapid re-compaction occurring. Visual signs of soil compaction damage include areas of poor growth and high weed composition in the pasture sward or large areas of bare ground. Generally these signs indicate sub-optimal aeration in soils and corresponding poor pasture growth.

Preventing soil damage

Grazing strategies that prevent, as oppose to repair, soil compaction can help mitigate the soil physical damage and therefore are of value from an environmental and production perspective. Recently, the use of off-grazing management facilities has become more widespread within the dairy industry and can provide multiple benefits to a farm system such as: controlled effluent returns to land, controlled feed supply, thermal stress control and decreased soil damage from animal treading. However, little guidance is available to farm managers to make accurate decisions designed to decrease the likelihood of animal treading damage. A penetrometer described in Betteridge et al. (2003) can be used as a decision support tool to identify soil conditions that would result in treading damage if a soil is grazed by cattle. The penetrometer was developed specifically as a farmer-based tool rather than a complex and scientifically accurate instrument. It has been promoted amongst New Zealand farmers as a means to identify the risk associated with grazing pastures when soil water contents are high. Greater precision around grazing exclusion decisions can be made using soil moisture monitoring equipment. Given the influence of specific soil qualities on a soil's resistance to compaction, 'threshold' moisture content could presumably be determined at which grazing is not advisable. The critical moisture content (CMC) at which the greatest level of soil compaction occurs is illustrated in Figure 2. This approach is currently being tested at a research

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site in North Otago as a decision making criteria for grazing exclusion (simulating an off-grazing strategy).

Farm management options

Grazing management

Currently farmer evaluations rely on a visual soil assessment of the potential pugging risk as the trigger to (1) exclude cattle, (2) reduce the grazing period or (3) lower the stocking density in order to protect soils from excessive treading damage. A TREAD Ready Reckoner developed by Betteridge et al (2003) describes the relationship between grazing duration and stocking density and provides farmers with a guide to expected percentage reduction in yield for the month following treading. To illustrate how the TREAD toll may be applied, two worked examples are provided below.

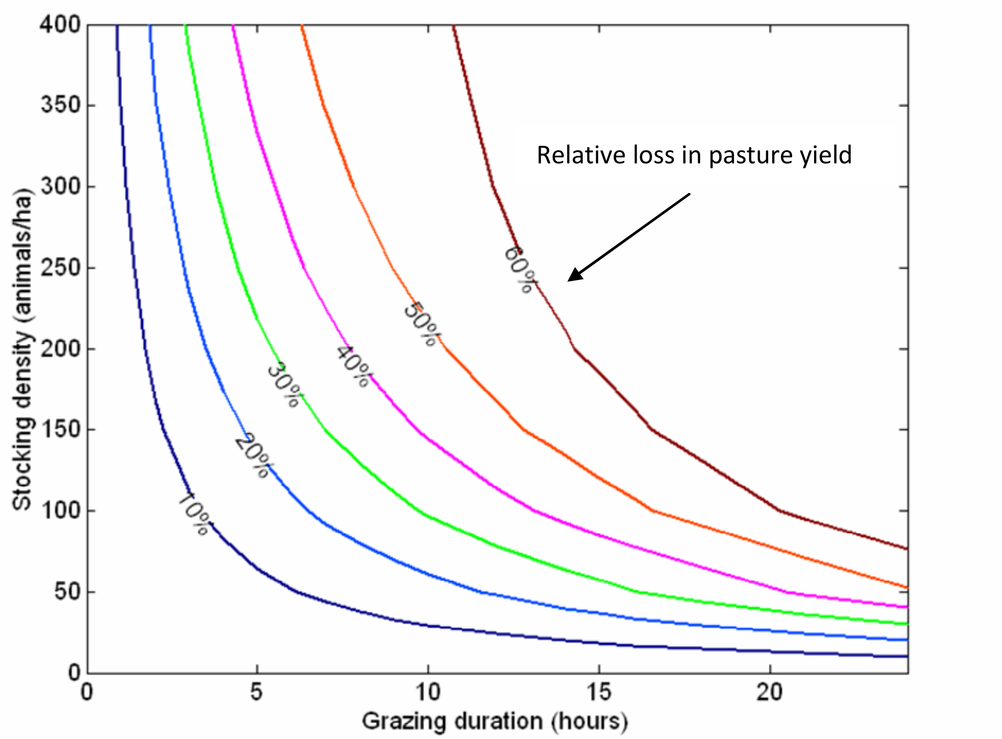

Figure 5. TREAD Ready Reckoner of potential pasture yield loss (%) for the month following grazing (from Betteridge et al. 2003). Lines represent the relative loss of pasture yield

Example 1: If 100 cows/ha remain on soils that are liable to be damaged (i.e. correspond to the CMC) , after 3.5 hours, 10% of the pasture yield potential would be lost; after 6 hours, 20% of the growth potential will be lost.

Example 2: If cows graze 12 hours and 20% loss of pasture yield potential is acceptable, the stocking rate should be 55 cows/ha. If the 55 cows/ha stay for 24 hrs, 50% of the pasture yield potential is lost.

Restricted grazing

Decreasing grazing duration whilst maintaining normal stocking density requires the provision of an off-grazing facility for animals. Research has shown that cows can take in approximately 80% of their daily dietary requirements in a 4 hour period (Ward and Greenwood 2002). Furthermore research has shown that decreasing animal grazing to a 4 hour period during periods of high soil moisture can considerably minimise the extent of soil physical damage. Therefore we recommend that where off-grazing facilities are available, cows be removed from pasture during critically wet periods (i.e. when soils reach a CMC) in order to prevent soil treading damage and protect the pasture sward.

The period that animals remain off pasture will determine the degree of animal welfare and effluent management issues that needs considering (DairyNZ 2005). Rudimentary options such as gravel based laneways or concrete areas are only short term propositions as animal lameness and inappropriate containment of effluent becomes an issue. Animals can be stood off for short periods of time on an area of approximately 5-6 m^2 per cow. However if animals are spending 12 hours a day or more off the paddock then they will require approximately 9-10 m^2 and a dedicated animal feeding facility to supplement their decreased pasture intake. The minimising muck, maximising money booklet (DairyNZ 2005) provides considerable management advice with regards to designing an off-grazing facility customised to the farm requirement. Where it is expected that animals will spend considerable time off paddock then a system to capture and contain all excreted effluent and roof over the animals (and in some cases effluent) to prevent significant rainfall dilution and maintain animal thermal control will provide the greatest long-term benefit.

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Strategic management recommendations

- Graze more strategically by knowing the soil types and their respective vulnerability to being compacted at different times of the year, for example utilise soils with greater resistance to compaction (free draining, sandy soils) during wet periods.
- Where heavy and poorly drained soils are prevalent consider an investment in an off-grazing facility to restrict grazing duration during expected wet periods.
- Winter animals within housing facilities or winter all stock off the milking platform to protect spring growth potential. It is acknowledged that wintering off the property can relocate the problem to a different area

Tactical management recommendations

- Monitor weather and soil moisture in order to predict wet periods that are likely to raise the soil moisture content and encourage soil damage.
- Maintain pasture cover and feed cows well
- Consider providing larger breaks (if break feeding) or paddock area during wet periods to decrease stocking density, increase pasture grazing residual and keep cows from moving around
- Consider putting a back fence behind a fresh break during wet periods to prevent previously undamaged or partially damaged soils from becoming further trampled.

Conclusions

- Two forms of soil treading damage exist; soil compaction results in compression of soil airspace whilst soil pugging remoulds wet soil around an animal hoof. Both have a negative effect on pasture growth and can increase soil water run-off. Pugging can damage the pasture sward in the short term, while compaction can decrease plant growth potential in the long term.
- The factors that influence the degree of soil treading damage are: soil moisture, livestock loading, grazing intensity, grazing duration, vegetative cover and soil susceptibility to damage.
- Soil treading damage can decrease the soils ability to transmit and store air and water with associated increases in the potential for poor drainage and surface runoff generation.
- Soil recovery of treading damage can take place naturally if the cause is removed.
- Mechanically loosening the soil can improve aeration and instigate the process of soil structural repair. However the longevity of mechanical loosening under different soils, climates and subsequent compaction pressures is often unknown.

- The prevention of soil damage requires management intervention to decrease the influence of soil risk factors. For example off-grazing facilities can be used during periods of high soil moisture to minimise or avoid soil treading damage.
- Know your soil types and have strategic and tactical plan for getting through wet periods

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