Northland Pastoral Extension Research Stocktake

Soil Management in Northland – Pugging

CONTENTS

1.0 Back to Grassroots – understanding soil structure and its Effect on Production

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Publication for series of seminars, in Northland, March 1994

Publication Overview:

- Publication covers:
  - An introduction to soil structure
  - Soil structural failure
  - Alleviating soil compaction
- Soil compaction is the major cause of poor soil structure

Southland Research

Winter treading by sheep at stocking densities typical of the all-grass wintering systems, can result in significant soil structural damage. Intensive winter grazing in this and other wet environments can result in significant losses of soil macropores. As a result, the transmission of water through the root zone is significantly restricted. After rain, this can lead to water-logging and soil oxygen deficit. Pasture production can be severely reduced, especially in early spring.

Factors affection the severity of compaction

- soil water content
- soil type
- treading pressure
- initial soil structure

1. Soil water content

Grazing when soils are very wet soil causes structural damage and deformation. But damage also occurs when soil water content is much lower. It is likely that the incidence of soil compaction is most severe at a water content near to field capacity. While damage may not be visible at the soil surface, compaction may occur to considerable depth. In wet regions, significant treading damage is not restricted to wet winter periods, but is likely to occur whenever soil water content is close to field capacity. This can arise after rain at any time during the year, and after excessive irrigation, if grazed immediately afterwards.

2. Soil type

Different soils can tolerate different intensities of treading before damage occurs. Such variations between soils are due to differences in such properties as texture, the type of clay mineral, and drainage characteristics. Fine-textured soils hold more water and are more prone to damage than coarse-textured soils.

The proportion of clay is also important as soils with a high clay content are usually poorly drained, generally wetter, and thus more susceptible to compaction. But a high clay content often imparts a significant shrink/swell characteristic to a soil. A compacted clay soil often shrink during drying, and the resulting cracks replace large pores which were lost during compaction. They also increase the rate of soil structure recovery. These cracks will increase nutrient leaching risk during heavy summer rainfall events.

3. *Treading pressure*

Cattle impose a higher treading pressure on the soil surface than sheep. Whereas static pressures imposed by sheep are approximately 100 kPa, those of cattle may be 200-400 kPa. Therefore, cattle hooves can be significantly more damaging to soil structure than damage associated with sheep treading. Increasing the grazing density with either animal species will increase the extent of compaction imposed.

4. *Initial soil structure*

Weakly structured, low strength soils are most susceptible to compaction. Newly cultivated paddocks and those recently re-sown or subsoiled will generally not have regained their structure and so will have low soil strength. These soils are at most risk of compaction and should not be heavily stocked when wet. A single mistreatment of such a paddock can have effects lasting several months.

Effect of soil compaction

- Increased soil compaction may reduce the penetration of roots into the subsoil. In a North Otago experiment for instance, loosening a compacted subsoil increased rooting depth from 43 cm to 69 cm, and total root length by 73%. In dry conditions, the subsoil is an important reservoir of plant-available water. Therefore, a restriction of root growth resulting from soil compaction reduces water uptake by plants and increases their susceptibility to drought.

- By reducing the volume of macropores, compaction can significantly restrict the movement of water through the soil profile. For example, in Southland work, intensive winter grazing with sheep reduced the rate of transmission of water through the soil tenfold. Such an effect of compaction increased soil susceptibility to water logging and root-zone oxygen deficiencies (anaerobic conditions) after rain. Under anaerobic conditions, root growth and activity was reduced so that uptake of water and nutrients was restricted. Further, greater amounts of soluble nitrate may be lost by denitrification. As a result, plant growth can be significantly reduced, especially in the spring.

Improving Soil Structure in Northland

Farm Management

To a certain extent, compaction problems and soil structural damage can be reduced or eliminated by careful grazing management. Even during peak lactation, cows can achieve full feeding in one third of the day, given an adequate pasture allowance. If the soil is wet, then the cows should be somewhere else for the other two thirds of the day. Feed pads, sacrifice paddocks and on/off grazing are all old ideas that need re-emphasis. Northland farms often have a mixture of different soil types on them. Graze the wetter soils early in winter before they become too wet, and never during heavy rain or when soils are water-logged.

Encouraging natural soil structure building processes

A build up of organic residues aids structure, as does the associated increase in soil microbes, fungi, nematodes and earthworms. Generally, fertilizers that increase the rate of pasture production will increase the rate of soil organic matter accumulation. Lime also aids soil structure by encouraging worm and microbial activity and directly by increasing the bonds between some clay particles. In trial work at Kaikohe, a range of soil structural stabilizing products were added to a poorly-structured soil. These included very high rates of animal manures, seaweed, lime, gypsum, cement, polyacrylamides and PVA glue. Nearly all had a beneficial effect but none could be considered economic at present. Wetting and drying cycles are also very important in developing structure, but the degree of drying required to develop deep cracks in the soil is detrimental to pasture productivity.

Subsoiling

Although natural processes will, with time, restore damaged soil structure, the use of subsoilers can make the process considerably quicker. Subsoiling (sometimes also termed aerating, ripping, or subtillage) is the loosening of soil by rigid tine equipment, but without cultivation and without mixing of the different soil depths. It must not be confused with mole ploughing (sometimes also termed subsoiling) which is carried out solely to drain wet soils. There is a wide range of subsoiling equipment which, in pastures, is usually operated at depths of 20-40 cm to loosen compacted soil.

When such an implement 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 full depth of loosening upward to the soil surface, and can therefore act as pathways for root penetration and for the transmission of excess water.

However, to properly improve drainage of the whole soil profile, soil below the subsoiling depth should be well drained. Aerating soils on flat topography with poor underlying drainage is not recommended for wet districts as it simply moves the zone of water-logging deeper into the soil, resulting in a soil which is difficult to manage and prone to severe re-compaction.

Subsoiling results – Kaikohe

During the first two years of the trial, subsoiling resulted in a 20% increase in pasture production and a large increase in the proportion of ryegrass in the pasture. Surface soil water contents and subsurface water table heights were also significantly reduced.

Associated with this was a 30% increase in root volume during winter.

Drainage effects were more consistent at the steeper gradients, as water was able to move more quickly through the loosened soil down slope. Subsoiling is not recommended on flat land where water will not be able to escape sideways. However, in Kaikohe, re-compaction of subsoiled plots occurred each year and repeated subsoiling was necessary. Despite this requirement, subsoiling is likely to be economically viable on poorly drained, compacted clay soils in Northland.

Identifying compacted soil

Close field examination of soil profiles to identify compact zones is fundamental to assessing the impact of treading and the need for aeration. Small pits should be dug in soil to a depth of about 50 cm for this assessment.

Compacted soil may be indicated by an accumulation of roots, or water just above or within the compacted zone. Other signs include: a lack of large pores – expressed by the existence of 'gleyed soil' (a bluish-grey colour caused by long-term water-logging); the absence of roots; the absence of earthworm activity within the compacted soil; and, that the absence of structural units in the soil. Compaction damage can be assessed by prodding the soil with a knife or penetrometer.

SUMMARY

Research at Kaikohe with subsoiling gave:

- 20% increase in pasture production
- An increased proportion of ryegrass in the pasture
- Lower surface soil water and subsurface water table heights
- 30% increased root volume during winter
- The need to repeat the subsoiling each year because the soils compacted

Subsoiling must be done in autumn or spring, when soils are moist but not wet.

The sub-soiler needs to be operated at the correct/critical depth for maximum results. This is indicated by a crescent shaped pattern of soil disturbance.

Farm management is important for improving soil structure: when the soil is very wet stock should not be grazed! Feeding pads, sacrifice paddocks, on/off grazing should all be considered as complements to grazing management.

Also, graze wettest paddocks while they are still dry! Implement a drainage policy.

Encourage natural soil structure building processes. The build up of organic matter and plant residues aids structural development. Fertiliser and lime help by increasing pasture growth and nutrient cycling.

Stock Policy

Hoof damage by sheep – 100 kPa.
Hoof damage by cattle – 200-400 kPa.

Increasing the grazing intensity with either animal species will increase the degree of compaction. If possible, use smaller animal species and lighter animal classes on soils prone to treading damage when wet.

Initial soil structure is important. Weakly structured soils are most susceptible to compaction.

Newly cultivated paddocks and those recently re-sown or subsoiled may not have regained their structure before being grazed. They are at most risk of compaction and need lighter stock densities, smaller animal species and classes within species..

Southland Research

Winter treading by sheep under intensive all-grass wintering systems can cause significant soil structural damage. With a loss of soil macropores, water flow within the root zone is reduced. This severely reduces pasture production, especially in early spring.

2.0 Impact of beef cattle grazing systems on treading damage and forage supply

Reference: GW Sheath and CJ Boom
Proceedings of NZ Grassland Association, 1997, Vol. 59 pages 87 to 91.

Overview

Levels of treading damage were measured under a range of cattle feeding and grazing management regimes. These were compared during winter and spring.

Soil surface damage was higher in farmlets with heavier cattle (390 kg versus 200 kg steers) and on paddocks where feeding was restricted through the use of a slow rotation (100 to 120 days versus 35 to 40 days).

Trial work was undertaken at Whatawhata Research Centre, west of Hamilton.

Method

Experiment 1:
Treatments were either:

- Rising 1 Year (R1) (200 kg liveweight) - an opening liveweight of 800 kg/ha, or
- Rising 2 Year (R2) (390 kg liveweight) - opening liveweight of 630 kg/ha, Angus steers managed in either, a
  - Fast rotation (FR), or a
  - Slow rotation (SR) during May to mid August

Experiment 2:
Treatments were:

- Three pasture allowances (high, medium and low),
- Two sex/breed differences (Friesian bulls or Angus steers), being 2-year-old cattle.

All land was easy contour. Grazing duration was 3-4 days. Pre graze pasture mass was similar between treatments and differing pasture residuals were used to generate the feeding allowance. Treading damage was the visual score of percentage of the surface soil compacted or pugged.

Results:

Experiment 1:

Table: Effect of cattle class and speed of grazing rotation on pasture response.

Stock class & rotation (R) speed	Steer LW (kg)	Grazing rotation (Days)	Pre-graze herbage (kg DM/ha)	Post-graze residual (kg DM/ha)	Treading damage (%)	Basal ground cover (%)
1993						
R1 FR	212	45	2547	1183	34	13
R1 SR	198	123	3175	682	35	26
R2 FR	406	46	2367	994	39	20
R2 SR	377	115	3306	699	55	36
1994						
R1 FR	208	37	1912	1118	25	18
R1 SR	197	103	2410	823	18	36
R2 FR	366	40	2150	1155	18	21
R2 SR	338	99	2630	758	18	46

Points:

- Where cattle were grazing to lower residuals in the slow rotation, higher levels of bare ground were seen. It was only in the R2 farmlet that high soil surface damage occurred.
- Within the R1 treatments, damage levels were similar
- Heavier R2 steers caused more damage and created more bare ground
- During 1993, pasture damage was similar for R1 slow rotation cattle and the two fast rotation farmlets (R2 slow rotation caused the most damage)
- During 1994, similar results for 1993, until mid-July when soils became wetter, and damage levels were higher. Then the R1 slow rotation farmlet had similar damage as the R2 slow rotation.

Damage in relation to monthly rainfall

	1993	**1994**
Rainfall mm – July	39	250
Rainfall mm – August	129	153
Treading Damage (% soil surface damaged)	5th August	9th August
R1 SR	39	48
R1 FR	40	30
R2 SR	53	72
R2 FR	47	30

Experiment 2:

There was no significant difference in treading damage between the bulls and the steers. Data shown below is an average of steers and bulls

Table: Effect of herbage allowance on treading damage and herbage loss.

Allowance	**Steer LWT (kg)**	**Total grazed area (Ha)**	**Pre-graze herbage (kg DM/ha)**	**Post-graze residual (kg DM/ha)**	**Treading damage (%)**	**Buried pasture (kg DM/ha)**
Winter						
High allowance	441	13.1	2458	1394	39	240
Medium allowance	424	8.6	2407	987	54	300
Low allowance	408	5.8	2379	647	64	346
Spring						
High allowance	533	14.1	2468	1599	23	196
Medium allowance	511	8.8	2473	1162	31	235
Low allowance	472	5.6	2451	728	37	265

Points:

- Cattle were heavier in Experiment 2 which, combined with wetter soil conditions, resulted in greater treading damage than in Experiment 1
- As feed allowance decreased, grazing residuals fell and soil surface damage increased. At the lowest herbage allowance, an average 64% of the soil surface was damaged during winter
- In spring, treading damage was half of that in winter
- Average amount of trodden (buried) herbage for a single grazing ranged from 240 to 340 kg DM/ha in winter, but from only 200 to 260 kg DM/ha during spring

DISCUSSION

- A slow rotation aimed at maintaining with R2 cattle liveweight resulted in 45-65% damage to the soil surface. This represents a loss of up to 340 kg DM/ha of the pre-graze herbage, or 20% of available feed.
- At higher feeding levels (high residuals, fast rotations) herbage loss from treading was 150-200 kg/ha for R2 cattle and 100-150 kg DM/ha for R1 cattle.
- The potential downside of reducing grazing intensity by adopting a faster rotation is an increasing chance of running into a feed deficit in late winter. Also, if the fast rotation means paddocks are grazed a second time;
    - Feed levels will be lower for that second grazing and animals will move around more, potentially causing more pugging damage
    - Forage loss and grazing damage from two grazing is likely to be the same or higher, than from a single grazing
    - The soil is likely to be softer during that second grazing

- Single treading events have carry-over effects on spring pasture growth. For example, when 60% of the soil surface was damaged, pasture growth rates were reduced by 10 kg DM/ha/day in August – September; at a time when normal growth rates may have been 25-30 kg/day; this being a 30-40% reduction in daily growth
- This trial did not examine the severity of treading damage; i.e. how deep or bad the treading damage was

3.0 What impact does dairy cow pugging have on clover N fixation and long term farm production?

Reference: J Menneer, S Ledgard, G McLay, W Silvestor.

Proceedings of NZ Grassland Association, 2001, Vol. 63 pages 63 – 67.

Overview

The effects of a single, moderate or severe pugging event in early spring on pasture production, clover growth and nitrogen fixation were measured.

Carried out on a poor draining Waikato soil, on a dairy farm.

Method

Pasture was dominated by ryegrass and white clover. Treatments consisted of a single pugging event of three severities: nil, moderate or severe.

Moderate and severe pugging treatments were trodden by dairy cows, at typical grazing intensity of 4.5 cows/100m^2 for 1.5 and 2.5 hours, respectively.

Rainfall with irrigation, ensured soils were near saturation when the pugging treatments started.

Results

Soil physical measurements:

- Air-filled porosity decreased from 16% in the non-pugged to an average of 11% for the moderately and severely pugged treatments. This reduced porosity resulted in restricted air and water movement in the soil.
- Bulk density was not affected by pugging as water-filled pore-space cannot be compacted.

Pasture production:

- Pasture production for the 12 months following the pugging event, decreased by:
    - 21% for the moderate, and
    - 45% for the severe pugging

- The largest decrease in pasture growth occurred during the first 100 days, with 52% (moderate) and 88% (severe) decreases measured.

Table: Effect of pugging on annual pasture yield (kg DM/ha) and nitrogen fixation severity.

	Pugging severity		
Measurement	**Nil**	**Moderate**	**Severe**
Total pasture yield	8168	6456	4526
Clover yield	1887	1601	660
Total N fixed (kg/ha/yr)	151	109	45

Points

- Annual clover production (kg DM/ha) decreased 15% and 65% under moderate and severe pugging, respectively. This effect on clover growth persisted for 160 days and 260 days under moderate and severe pugging, respectively.
- Under severe pugging the annual clover DM yield reduction was much greater than for grass (65% versus 38%) – clover was more susceptible to pugging damage than ryegrass.

Nitrogen Fixation

- Nitrogenase activity, using the acetylene reduction method, was used to measure N fixation
- Pugging treatment decreased, by up to 90%, N fixation within 3 days of pugging. This was due to:
  - Decreased in air-filled porosity
  - Clover root DM mass at 3 weeks, decreasing by 64% and 91% in moderately and severely pugged treatments, respectively; these root mass decreases, were probably due to direct treading damage.
- On an annual basis, the total amount of N fixed decreased from:
  - 151 kg N/ha in the Control, to
  - 109 kg N/ha (↓ 28%) in Moderate and
  - 45 kg N/ha (↓ 70%) in Severe treatments

Modelling results

Model farm evaluation based on:

- No N fertiliser used
- Producing 1000 kg milk solids/ha/year
- Over a 10-year period, with annual Moderate or Severe pugging events imposed:
  - N fixation was reduced by 28% and 70%, and
  - Grass yield was reduced by 21% and 44% respectively

Modelled Parameter	Control	Pugging Severity	
		Moderate	Severe
Clover yield (kg DM/ha)	4537	3393	1152
Grass yield (kg DM/ha)	10765	8474	6070
N fixation (kg N/ha)	176	132	50
Soil organic N (kg N/ha)	0	-21	-47

Soil organic N predicted to decline because of reduced N fixation. Milk production loss after 10 years, due to reduced pasture production was:

- 21% under Moderate pugging
- 54% under Severe pugging

On a whole farm basis, if moderate pugging occurred on 50% of the area and severe pugging on 10%, this would see a reduction of 16% (from 1000 to 840 kg MS/ha/year) This equates to a loss of$800/ha @$5.00/kgMS.

4.0 Project: Managing soils on beef farms in Northland

Author: G Ussher,

Northland Beef Farming Group Final Report to MAF Sustainable Farming Fund, August 2004.

Overview

A three-year project covering on-farm monitoring plus extension activities. Aimed to increase awareness by Northland beef farmers of the potential financial gain from a major reduction in pugging damage and to increase meat production by 8-10% on the project farms by reducing pugging damage to pastures.

Method

Soil mapping on farm to highlight areas that were more or less sensitive to pugging damage.

On-farm sampling in the treading area:

- Soil macroporosity
- Soil moisture and temperature
- Clover content in pastures from which soil samples were taken
- Soil fertility

Farmer discussion regarding activities that could be adopted to minimize pugging damage. Followed by farmer adoption of some of these activities. Extension activities were undertaken.

Macroporosity

- Percentage of soil volume occupied by these important large pores
- An ideal soil has a macroporosity of 16-20% in the surface 0-5cm layer and will produce the highest pasture production
- Trials have shown that for every 1% increase in macroporosity there is a 1.8% increase in relative pasture yield
- In Southland studies, a macroporosity of 8% was associated with a relative yield of 81%. That is, a pasture producing 11,000 kg DM/ha/annum at 20 % macroporosity would produce 8910 kg dry matter per hectare per year at 8% macroporosity.

Northland Project Results

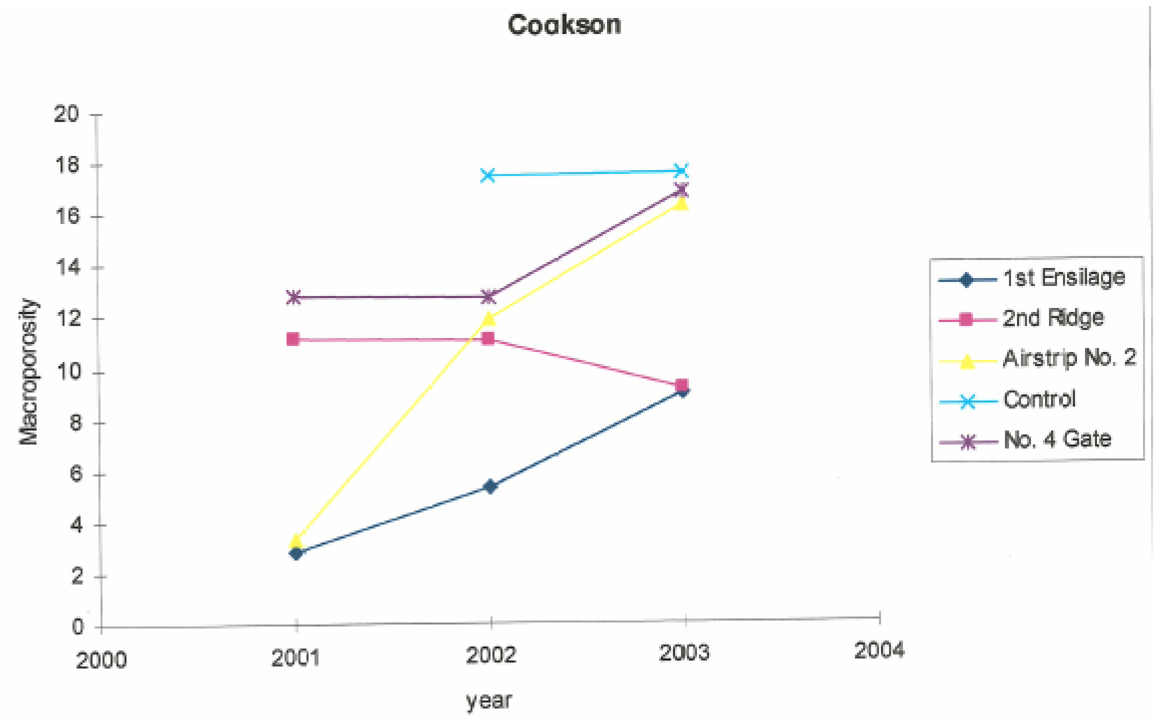
Three years of data from 4 paddocks on each of 8 properties plus a ‘Control’ area from under the fence-line on each farm. There were some inconsistencies in results often because the farmers and researchers were unable to distinguish between soil damage done in recent times versus long term damage. Nevertheless, by considering all sites over 3 years (see “average over all farms” graph) a definite trend in the data was found.

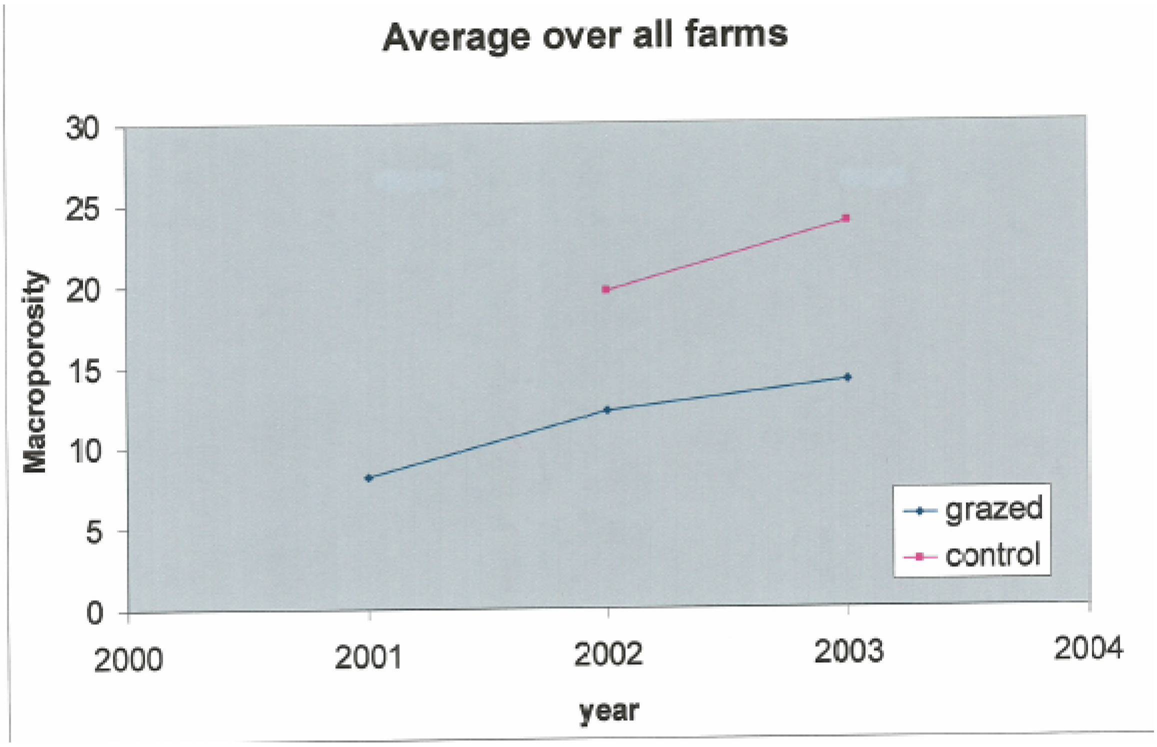
Average macroporosity for all farms

2001	8.2%
2002	12.2%
2003	14.2%

- The difference from 2001 to 2002 was statistically significant but not between 2002 and 2003. Year 2003 was the worst winter of the three and to even hold its own was considered an achievement!
- In effect, the macroporosity moved 6 percentage units over the 3 years which is equivalent to a 10.8% (1.8% x 6) increase in potential pasture production
- The potential macroporosity across all farms ranged between 19.6 and 23.8% (2002 and 2003) as indicated by the Control samples under fence-lines

Geoff Cookson's graph shows that three of the four paddocks had a trend of increasing macroporosity over the 3 years and two (Airstrip No. 2; No. 4 gate) approached the potential value for the farm.





Additional results

Soil moisture levels, clover percentage of the pastures and soil temperature were recorded in test paddocks.

Soil moisture – Whole farm

	2001	2002	Nov 2003
All-farm mean (%)	62	47	40

Clover percentage

	2001	2002	2003	3-year average
All-farm mean (%)	11.5	14.2	13.4	11

The overall clover population across all farms for the 3 years was 11.3%.

Soil temperature

All-farm average temperature was 16.5 ºC in 2001, 14.6 ºC in 2002, and 16.9 ºC in 2003. The drop of almost 2 ºC in 2002 compared to 2001 largely explains why spring 2002 was bad. A 4-week later sampling in 2003 compared to both 2001 and 2002, may account for the soil temperature in 2003 being apparently warmer than in 2002.

Project farmer activities

Undertaken to reduce pugging damage.

Farmer 1 - Farming smaller animals; e.g. dry dairy cows replaced by dairy weaners.

- Any older/heavier animals are moved more quickly – grazing management.

Farmer 2

- Improved subdivision
- Reduced number of older bulls before the wet winter sets in
- Improving kikuyu control by breeding cows

Farmer 3

- Farming young cattle through winter
- Carrying lambs through winter on wet country
- Increased subdivision: target being to improve young cattle growth rates

Farmer 4

- Not carrying 2-year bulls through the winter
- Improving growth rates in younger cattle through subdivision and re-grassing
- Drainage coil used to tap very wet areas [
- To "look after" the best pastures as much as possible

Farmer 5

- Used short rotation ryegrass to improve winter growth rates of young cattle
- Use of groundhog for subsurface drainage/aeration
- Selling older cattle before July
- Future: considering a feed pad

Farmer 6

- Subdivision
- Grazing management to focus on daily shifts?
- Farming lighter cattle - bigger cattle (over 450 kg) sold by end of June

Farmer 7

- Use of a feeding/loafing pad on dairy platform
- Use of subsoiler for aeration work in spring

Farmer 8

- Move to wintering lighter stock
- More break feeding
- Mapping the farm

The principals discussed by the group can be summarised as:

- Small cattle cause less pugging damage compared to bigger cattle
- Quieter cattle cause less damage than wild or aggressive cattle
- Well fed cattle cause less damage than hungry cattle
- Sheep cause less damage than cattle
- Lambs cause less damage than breeding ewes

5.0 ***Effect of treading by dairy cattle on topsoil physical conditions for six contrasting soil types in Waikato and Northland, NZ, with implications for monitoring***

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Author: P Singleton, M Boyes, B Addison.

NZ Journal of Agricultural Research, 2000 Vol. 43 pages 559-567.

Overview

A study of the physical condition of soils under dairying in the Waikato and Northland regions was undertaken to determine:

- The physical condition of the soil
- Possible changes from pugging damage
- The most appropriate measurements and sampling regimes for monitoring change

Method

Northland soils selected were:

- Kiripaka clay: free-draining soil, having a strong micro-aggregate structure resistant to treading damage
- Kara soil: poorly drained in winter and very susceptible to pugging damage
- Waiotira clay: imperfectly drained and being "in between" the Kiripaka and Kara soils for susceptibility to treading damage

Sites on each soil were:

- Never trodden (under long-established fence lines)
- Usual conditions (representing an average paddock and pasture condition, assessed by the farmer)
- Previously pugged (pugged at least 18 months previously and having been grazed normally and now being in an "apparently recovered" state, with pasture growth being normal

Farms were typical dairy farms. Stock densities had been stable for 5 years and dairy-farmed for 25 years. Farms used strip grazing in winter, with on-farm wintering. Cow densities were 300 to 600/ha. In very wet conditions cows were sometimes taken off the paddocks. Pastures were perennial ryegrass and white clover; at least 5 years old.

Results

- For these Northland soils, only hydraulic conductivity (K_{sat} and $K_{-100\ mm}$ – flow rate through macropores and micropores respectively) and aggregate size class showed differences between treading regimes
- Bulk density, total porosity and pore size distribution did not show significant differences between treading regimes for Northland soils, whereas they did for Waikato soils
- For most measurements, approximately 200 cores are needed per regime to show any statistical significance of treading effects. For hydraulic conductivity, 100 cores are needed for any comparison

Table: Mean values for soil properties (50-100 mm depth) for different treading regimes and soils in Northland. NT, never trodden; U, 'usual'; PR, previously pugged.

	Northland Soils								
	Kiripaka			Waiotira			Kara		
Soil Property	NT	U	PP	NT	U	PP	NT	U	PP
Bulk density	0.91	0.95	0.92	1.04	1.06	1.06	1.10	1.14	1.11
Total porosity (%, v/v)	62	61	62	57	53	57	55	54	55
K_{sat} (mm/hr)	76	57	24	223	26	25	28	9	5
$K_{-100\,mm}$ (mm/hr)	36	24	17	7	7	5	4	4	1
Pores > 60 μ (%)_	11.0	9.8	10.7	8.7	7.5	5.3	8.1	6.2	6.1
Pores >30 μ (%)	14.3	12.2	13.1	10.5	9.5	7.2	10.3	8.0	8.1
Aggregates <200 mm (%)	49	38	34	25	15	15	14	12	8
Aggregates >60 mm (%)	21	26	33	32	45	45	43	50	59

Discussion:

- Values of various soil physical measurements do not readily show significant differences between treading histories; especially for any one specific soil type. This lack of significant difference in some tests may have been the result of the 'Usual' treatment already showing effects of past treading damage.

- Range of data from the 'Usual' grazing treatment often overlapped with that of the Never Trodden treatment, indicating that it may be possible to graze pastures and still achieve soil conditions similar to that of Never Trodden pasture.

- Values for soil properties commonly showed a decline in soil physical condition from Never Trodden to Previously Pugged treatments, even when these differences were not statistically significant. Trends over time may be more useful for monitoring the effects of land management on soils rather than relying on statistically significant differences. These significant differences may not show any change in soil condition until there has been a serious decline. Trends over time may give an early indication.

- Results indicated that problems may arise in the future, under increasing stocking rates/increasing intensification.

- The one measurement that did highlight a critical decline in soil condition was macroporosity: the critical value of ≥10% being required for optimum plant health and reflecting adequate soil aeration.

- The short-term effects of pugging damage to soil and pasture are easily seen in the field. But, once the pasture has 'apparently' recovered, there can be on-going soil problems related to incomplete physical recovery:

    - More frequent and persistent ponding or soil wetness
    - Reduced soil aeration
    - Increased soil nutrient loss
    - Reduced efficiency in nutrient uptake e.g. nutrient availability is reduced
    - Reduced root penetration

- Possible on- and off-site effects of treading damage

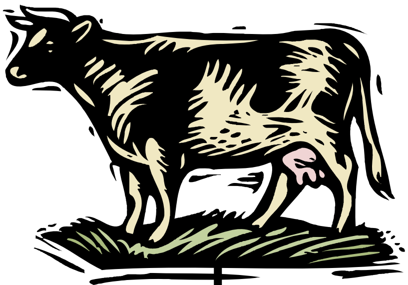
Pasture

- Plant death and damage
- Inadequate soil aeration
- Nutrient loss
- Reduced nutrient uptake efficiency
- Reduced root penetration

Greenhouse gases

- Increased emission CO_2, CH_4, N_2O

Treading effects



Catchment's water quality

- Increased runoff of
    - Water
    - Nutrients
    - Faecal coliforms
- Decreased catchment water quality

Soil Fauna

- Changes in microbial population
- Reduces earthworm population

Physical and chemical soil processes

- Compaction
- Loss of structure
- Decreased oxygen supply
- Chemical reduction of nutrients

6.0 Pasture renovation after winter pugging damage

Authors: R Johnson, D McCallum, N Thomson

Proceedings of the NZ Grassland Association, 1993, Vol. 55 pages 143-146

Overview

- On a severely-pugged area, seasonal and annual dry matter production of re-seeding treatments and non-seeded treatments were compared over 2 years
- Differences in production of the re-seeded treatments persisted over the 2-year study period, showing that "under-sowing" had a long-term beneficial effect following pugging

Method

- Trial carried out at Taranaki Agricultural Research Station on a Brown Loam (heavy clay) soil stocked with dry dairy cows using 24-hour block grazing regime. This caused severe pugging damage - hoof marks to 4-8 cm in depth
- Six weeks after this damage, treatments were established and monitored for 2 years
    - No form of repair (Control)
    - Harrowing
    - Rolling
    - Broadcast ryegrass seed followed by harrowing
    - Broadcast ryegrass seed followed by rolling
    - Drilling ryegrass seed followed by harrowing
- Trial area was hard-grazed to 4-5 cm with dairy cows before the treatments were applied
- Seed – 15 kg/ha of Yatsyn 1 perennial ryegrass
- First grazing was 23 days after treatments imposed, after which the trial area grazed as part of normal 30-day milking round
- Soil fertility was moderate – pH 6.1, K 11, Olsen P 16, and S 23

Results

- Perennial ryegrass plant density was, in decreasing order: Broadcast re-seeding > Drilled and harrowed >Rolled, Harrowed and Control

Table: Effect of renovation treatment on ryegrass plant counts 6 weeks after reseeding (plants /m^2).

Treatment	Ryegrass Density (No./ m^2)
Control	138
Harrow	134
Roll	188
Drill and Harrow	230
Broadcast and Harrow	313
Broadcast and Roll	304

- Botanical Composition
    - There were no differences between treatments for content of clover, weed or dead matter content
    - Treatment effects on pasture composition were most marked in spring of each year, at 15 and 27 months after treatments imposed: ryegrass content

increased and 'Other grasses' content decreased. Averaged over 2 years, ryegrass increased from 45% to 62% while 'Other grasses' content decreased from 39% to 24% with re-seeding
  - Detailed, seasonal pasture composition data are included in this paper
  - The major 'Other grasses' in order of dominance were: Cocksfoot, Poa annua, Poa pratensis and Couch

- Dry Matter Production
  Average annual DM production of the 3 re-seeded treatments was higher than without re-seeding – see below. The average for all the re-seeding treatments, gave increases compared to the Control.

Increase in DM/ha	**Year 1**	**Year 2**
Absolute increase (t DM/ha)	1.3	1.8
% increase	13	22

The main yield advantage from reseeding occurred during spring: an average of 16% greater DM production than the un-sown treatments. This yield improvement was from ryegrass. The increase in ryegrass yield between un-seeded and re-seeded treatments, was greatest in Year 1.

Table: Effect of Pugging renovation treatments on pasture and ryegrass yield (t DM/ha)

	Summer		Autumn		Winter		Spring		Total	
	Total	*Ryegrass*	*Total*	*Ryegrass*	*Total*	*Ryegrass*	*Total*	*Ryegrass*	*Total*	*Ryegrass*
1990/1991										
Control	2.9	1.4	1.5	0.8	1.8	1.3	3.9	1.9	10.0	5.4
Harrow	2.6	1.2	1.6	0.7	1.8	0.8	4.0	2.4	10.0	5.1
Roll	2.7	0.9	1.6	0.6	1.8	1.1	4.2	2.2	10.3	4.9
Drill + Harrow	3.0	1.7	1.9	1.2	2.1	1.1	4.7	3.1	11.7	7.1
B/Cast + harrow	2.4	1.5	1.8	1.3	2.3	1.5	4.8	3.7	11.3	8.1
B/Cast + Roll	2.5	1.2	1.7	1.2	1.9	1.6	4.8	3.8	10.9	7.9
1991/92										
Control	2.9	1.1	1.2	0.6	1.0	0.6	3.4	0.8	8.5	3.1
Harrow	3.6	1.1	1.1	0.5	1.0	0.5	3.4	0.6	8.9	4.1
Roll	3.4	1.7	1.1	0.7	0.9	0.6	3.3	1.1	8.9	2.7
Drill + Harrow	3.7	2.1	1.3	0.9	1.0	0.7	3.7	1.6	9.7	5.3
B/Cast + harrow	3.9	2.3	1.3	1.0	1.2	0.9	3.7	1.5	10.1	5.7
B/Cast + Roll	3.9	2.3	1.5	1.1	1.4	1.0	4.4	1.9	11.2	6.3

Discussion

- Harrowing or Rolling without re-seeding had no effect on pasture production or composition.
- Re-seeding of existing pasture is effective only when
  - Established (resident) plants are weak or absent, and
  - There are large areas of bare ground
- Optimum seedling establishment after broadcasting requires covering the seed with loose soil on trash.
- Bare ground and weak plants (from severe pugging) which is then broadcast sown, harrowed and rolled, will result in increased DM production

- Potential financial worth of successful re-seeding.

	Year 1	Year 2
DM Production Increase (kg DM/ha/year)	1,300	1,800 [1500? See çomments]
Utilisation	80%	80%
Conversion to milk solids (at 15kg DM to produce 1.0 kg MS) – kg MS/ha/yr	69	96
Milk Revenue Increase/ha (at $5.00/kg MS)	$346.00	$480.00

Combined milk revenue increase over the 2 years at $826 [? $746 (or $373/ha/yr)] (on average at just over $400/ha/year).

Tentative costs:

Seed / ha	$120
Application – drill	$ 80
Oversow	$ 40

A typical cost for seed plus application at around $180/ha.

To give a net revenue/ha of approximately $650[?$530] for the 2 years at $320[$265]/ha /year result.

This calculation ignores the potential dry matter advantage in future years: this trial ran for 2 years only.

7.0 Dairy grazing strategies to minimize soil pugging and compaction in the Waikato

Author: JJ Drewry

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Overview:

Three-year study compared grazing regimes for minimizing soil compaction and pugging damage.

Trial site was Dexcel No. 1 Dairy, Ruakura Research Centre, on a soil which is poorly drained and susceptible to pugging.

Method

Treatments were:

- Control: being conventional dairy grazing practice. In winter cows were block grazed with daily shifts. During lactation cows were grazed at 90 cows/ha
- Never Pugged: if soil was prone to pugging grazing was similar to Control except that when the soil was wet, pastures were not grazed. This strategy was to avoid pugging
- Grazed for only 3 hours when the soil was wet. This strategy to minimize pugging damage
- Never Grazed: cows excluded for the entire period of the trial

Results

Soil physical measurements

- Most soil physical measurements showed a clear and consistent pattern, with significantly more compaction at 0-5 cm for the more heavily grazed treatments. But no significant distinction between the treatments at 10-15 cm or 15-20 cm.

- For macroporosity there was a significant difference between heavily grazed and lighter grazed treatments at 5-10 cm at each sampling: for bulk density this contrast was not significant.

- Saturated hydraulic conductivity (water flow in large pores) showed a highly significant treatment effect: values increasing with depth over all treatments. Averaged over all samples and depths (0-20 cm), water flow in large pores was:

  - Control 129 mm/hour
  - Grazed 3 hours 238 mm/hour
  - Never pugged 965 mm/hour
  - Never grazed 1897 mm/hour

  Note: levels over 70 mm/hour adequate for good drainage

Table: Macroporosity results

Date	Depth (cm)	Control	Grazed 3 hours	Never pugged	Never grazed
Oct 97	0-5	12.8	16.3	21.3	21.6
	5-10	6.8	8.8	11.1	11.6
	10-15	10.9	12.0	12.0	11.7
June 98	0-5	11.2	14.0	19.9	22.3
	5-10	10.3	12.9	15.8	15.2
Oct 98	0-5	14.2	15.6	22.3	21.9
	5-10	10.7	13.0	15.2	16.8

Pasture Yield Measurements:

- Never Grazed and Never Pugged treatments had significantly greater yields than Control and Grazed 3 hours, during July – September period in 1997 and 1998. But in 1996, for July – September there were no significant differences.

- During October – December 1997, Never Grazed had a significantly greater yield than other treatments, but in the other 2 years this advantage was not significant.

- During July – September 1997

  - Never Grazed produced 35% (+ 826 kg DM/ha), and
  - Never Pugged produced 28% (+ 1021 kg DM/ha), greater pasture yield than Control.

Table: Pasture Yield Advantage: Never Grazed and Never Pugged relative to Control (100%), July – September periods

Period	Never grazed	Never pugged
July – September 1997	35%	28%
July – September 1998	49%	39%
July – September 3 year average	28% (772 kg DM)	21% (570 kg DM)

Table: Pasture yield (kg DM/ha) for the grazing treatments.

	Grazing Treatment				
Period	Control	Grazed 3 hours	Never pugged	Never grazed	
July – Sept 96	3155	2661	3282	3492	NS
Oct – Dec 96	4421	4130	3959	3956	NS
Jan – June 97	424	4053	3988	4306	NS
July – Sept 97	2942	3068	3768	3963	*
Oct – Dec 97	2493	2221	2443	3326	***
Jan – June 98	4201	3778	3250	4133	NS
July – Sept 98	1957	1935	2713	2915	*
Oct – Dec 98	4976	4571	4700	5115	NS

* $P<0.05$; ***$P < 0.001$NS - not significant

Discussion

- Although not always significantly different between treatments, soil compaction damage, as shown by the soil physical indicators, were generally greatest in order of Control (conventional grazing) > Grazed 3 hours > Never Pugged > Never Grazed

- The Grazed 3 hour and Never Pugged treatments were imposed on wet soil:
  - Four times in Year 1
  - Twice in Year 2

- Soils were wetter in Year 1 but the soil physical sampling only started in Year 2 which was relatively dry

- Overall, soil structure was good, with macroporosity generally >10%, which is used as a threshold for indicating good soil health

- Never Grazed had a greater average pasture yield than all other treatments, but this is not a practical option

- Never Pugged had a greater average winter–early spring yield than Control, but this did not show as greater yields for the full 12-month period

- Grazed 3 hours had some improved soil physical condition, but this was not reflected in greater pasture production

  Under soils that may be considerably wetter, e.g. Northland's heavy clays, podzols and limestone, this improved soil physical condition may well give greater pasture production.