Silt Recovery
Lower North Island Storm Event 2004

A report for the Sustainable Farming Fund, and Meat and Wool New Zealand

Annette Litherland[1], Margaret Brown[1], Michael Wilson[1], Douglas Benn[1], Leanne Stobie[1], Ian McNabb[1], Chris Hunt[1], Peter Kemp[2], Ian Valentine[2]

[1]AgResearch, Grasslands, Private Bag, Palmerston North
[2]Massey University

SUSTAINABLE FARMING FUND: PROJECT 05/060

Table of contents

Executive summary

In February 2004, the multiple flooding of rivers in the lower North Island resulted in the inundation of around 20,000 ha of farmland. At the time it was found that there was little published information on the recovery of flood affected pasture and what information was available was difficult to source. In addition no systematic attempt had been made to collate farmers' experience and knowledge on regrassing flooded pastures. The objective of this report was to collect information on farmers' perceptions and some data and past research information on the effectiveness of methods of regrassing for different silt depths. From this, best practise recommendations could be made for flood events in the future.

Two farmer datasets form the basis of this report. Firstly, the Massey dataset (M) of 52 farmers and 110 defined blocks (different regrassing strategies used in each block) was collected from November 2004 to January 2005. The Massey dataset was collected from a small random group of farmers followed by referrals. Secondly, the AgResearch dataset (AgR) was collected a year later from January to May 2006 from 52 farmers comprising 91 defined blocks. The AgResearch dataset was comprised of a random selection of flood affected farmers.

There are some clear differences in these two datasets. The Massey dataset is largely comprised of farmers with only shallow or no silt depositions while the AgResearch dataset has a much greater representation of farmers with deeper silt. Silt was classified as shallow at less than 6 cm, intermediate at 7-30 cm and deep silt at more than 30 cm. In some instances, farmers in the different datasets were asked different questions though the measurements conducted on the farm were comparable. Researchers in both datasets visited the farmers and collected measures of ground cover and silt depth.

The silt that covered the pastures had a high pH of 6.9, low organic matter of 1.6%, low Olsen P of 8 and very high sulphate levels of 27. This is indicative of largely unweathered material with little topsoil. There were only small differences in silt derived from different rivers. While in most cases water inundation only lasted a few days, this coupled with silt deposition, resulted in 80% of pastures dying (AgR). Over half of the silt smelt after the flood, indicating anaerobic activity.

For most paddocks (AgR), even those oversown and especially those with deep silt, regrassing didn't occur until more than 30 days after the flood largely because machinery couldn't get on the silted areas. The mean time from flood to first grazing was 5 months, though on shallow silt this time period was only 2.5 months and on deep silt was 7.5 months. First grazing on clay silt was delayed by 2 months on shallow silts and 4 months on deep silt relative to loamy or sandy silts.

Almost all regrassed flooded paddocks were later sprayed for weeds. However, this was more a case of weeds surviving the flooding, and out-competing grasses, than the silt containing a bank of weed seeds. Most flooded paddocks, irrespective of silt depth and cultivation method, had ongoing issues with poor drainage and pugging damage.

According to farmers (AgR), deep silt produced 50% and 35% less than unflooded paddocks 6 and 18 months respectively after the flood. However, the production loss from shallow silt was much lower and more transitory, in fact, some farmers believed paddocks that were regrassed on shallow silt were more productive at 18 months than the unflooded paddocks. Fertile clay and loam silts were 20% more productive than sandy silts after 18 months.

There was a large variability in ground cover following regrassing in both the Massey and AgR databases. Different regrassing methodologies explain only a relatively small (around 20%) variation in these ground covers.

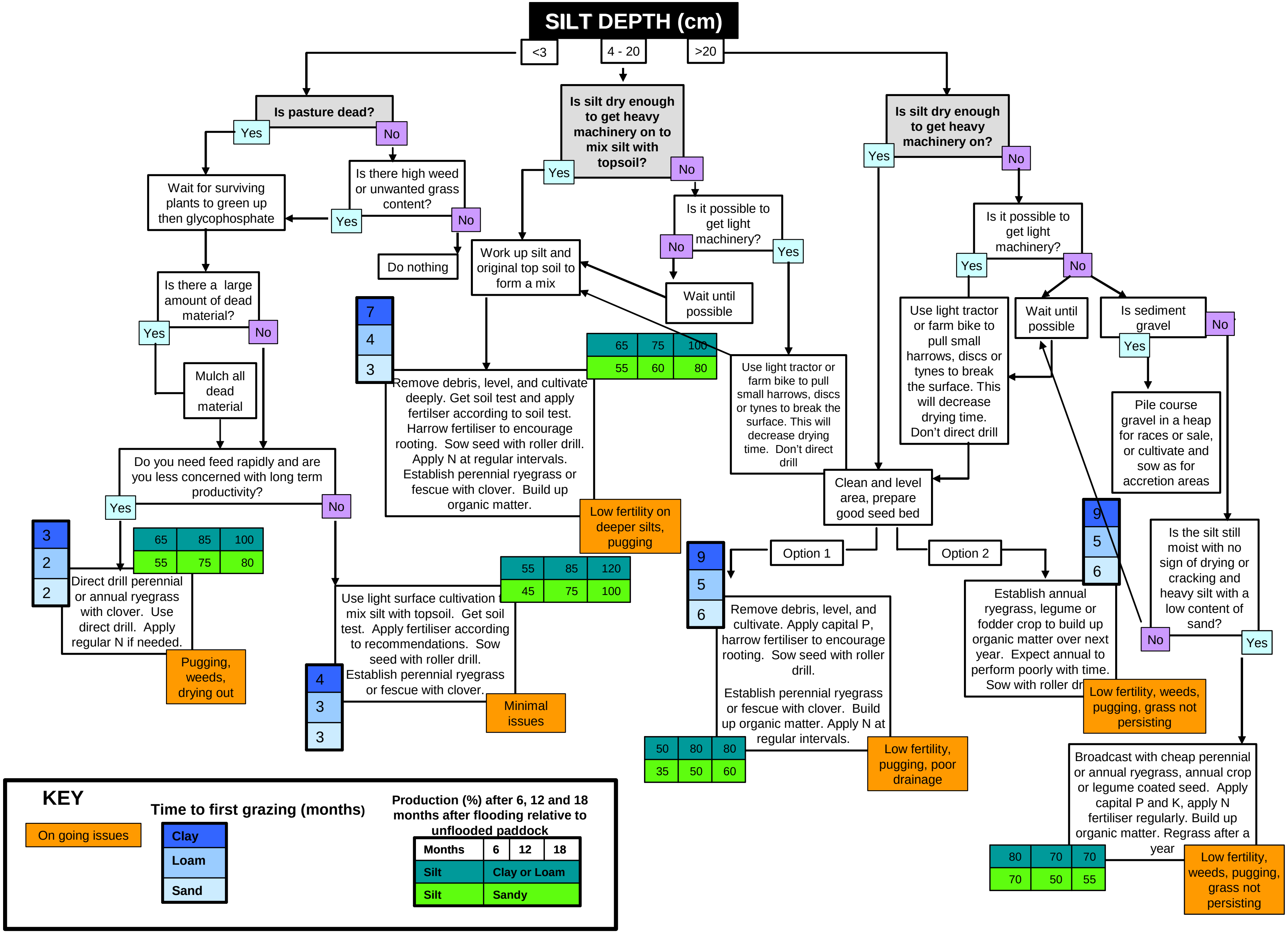
At six months, farmers assessed oversown paddocks as performing 30% better in the short term but 30% lower in the long term compared to fully cultivated paddocks on moderate silt depths. Farmers indicated that oversown paddocks had greater ongoing issues with low fertility. Measurements showed that full cultivation improved ground cover in flooded paddocks on deeper silts by 16% compared to minimal seed bed preparation. On shallower silt where pasture roots could eventually reach the topsoil, this difference was reduced but still persisted. Both the farmers' observations and measurements indicate that where possible, mixing topsoil and silt together is the recommended best practise. However, fully cultivating paddocks compared to direct drilling or oversowing delayed the time to first grazing by two months.

Farmers mainly used roller drills to sow seed in fully cultivated paddocks. When minimal cultivation had occurred, direct drilling was the method chosen for sowing seed in shallow silt, with less direct drilling and more roller drills or broadcasting used as silt depth increased. Measurements of ground cover showed that roller drills were less effective when used in conjunction with minimal cultivation. Conversely, direct drills were less effective if used on fully cultivated silts. In some cases farmers may have used suboptimal equipment due to availability issues.

Generic fertiliser recommendations for silt are for high rates of potassium and phosphate fertiliser and ongoing smaller rates of nitrogen (N). It is also recommended that efforts need to be made to build up organic matter in the soil. For farmers (AgR), urea was the most commonly used source of N particularly on paddocks that weren't cultivated. Surprisingly, some farmers didn't use N on flooded paddocks at all. When this happened on deep silt there was a strong shift toward legume growth. The average cumulated (over 10-22 months) rate of N used was 90 kg N/ha. Medium silts depths received 40 kg N/ha more N than shallow and deep silt. No statistical effect of N use on ground cover could be found. However, historical research results from Cyclone Bola indicate pasture growth rate on silt increases by 30-40% when DAP fertiliser is applied.

Most farmers sowed silt with perennial ryegrass clover mixtures. A few farmers sowed fescue and this performed well. A few more farmers sowed annual ryegrasses but these seemed to have performed poorly especially on the intermediate and deep silts when measured 10 and 22 months after the flood. Historical research conducted after Cyclone Bola on deep oversown silts found that dry matter production 5-6 months after sowing was 55% higher for an annual than a perennial grass. On February 2004 silts it was also found that alternative annual grass, cereal or legume crops performed well. But even with cutting and/or grazing of these crops, the recovery of organic matter in silt was slow.

A best practise decision tree was devised from the farmer survey information and the measurements taken on the flooded paddocks. It is presented on the next page.


SILT DEPTH (cm)
<3
4 - 20
>20
Is pasture dead?
Yes
No
Wait for surviving plants to green up then glycophosphate
Is there high weed or unwanted grass content?
Yes
No
Do nothing
Is there a large amount of dead material?
Yes
No
Mulch all dead material
Do you need feed rapidly and are you less concerned with long term productivity?
Yes
No
3
2
2
65
85
100
55
75
80
Direct drill perennial or annual ryegrass with clover. Use direct drill. Apply regular N if needed.
Pugging, weeds, drying out
55
85
120
45
75
100
Use light surface cultivation to mix silt with topsoil. Get soil test. Apply fertiliser according to recommendations. Sow seed with roller drill. Establish perennial ryegrass or fescue with clover.
4
3
3
Minimal issues
Is silt dry enough to get heavy machinery on to mix silt with topsoil?
Yes
No
Work up silt and original top soil to form a mix
7
4
3
65
75
100
55
60
80
Remove debris, level, and cultivate deeply. Get soil test and apply fertiliser according to soil test. Harrow fertiliser to encourage rooting. Sow seed with roller drill. Apply N at regular intervals. Establish perennial ryegrass or fescue with clover. Build up organic matter.
Low fertility on deeper silts, pugging
Is it possible to get light machinery?
No
Yes
Wait until possible
Use light tractor or farm bike to pull small harrows, discs or tynes to break the surface. This will decrease drying time. Don't direct drill
Is silt dry enough to get heavy machinery on?
Yes
No
Is it possible to get light machinery?
Yes
No
Use light tractor or farm bike to pull small harrows, discs or tynes to break the surface. This will decrease drying time. Don't direct drill
Wait until possible
Is sediment gravel
Yes
No
Pile course gravel in a heap for races or sale, or cultivate and sow as for accretion areas
Clean and level area, prepare good seed bed
Option 1
Option 2
9
5
6
Remove debris, level, and cultivate. Apply capital P, harrow fertiliser to encourage rooting. Sow seed with roller drill.
Establish perennial ryegrass or fescue with clover. Build up organic matter. Apply N at regular intervals.
50
80
80
35
50
60
Low fertility, pugging, poor drainage
Establish annual ryegrass, legume or fodder crop to build up organic matter over next year. Expect annual to perform poorly with time. Sow with roller dr
9
5
6
Low fertility, weeds, pugging, grass not persisting
Is the silt still moist with no sign of drying or cracking and heavy silt with a low content of sand?
No
Yes
Broadcast with cheap perennial or annual ryegrass, annual crop or legume coated seed. Apply capital P and K, apply N fertiliser regularly. Build up organic matter. Regrass after a year
80
70
70
70
50
55
Low fertility, weeds, pugging, grass not persisting
KEY
On going issues
Time to first grazing (months)
Clay
Loam
Sand
Production (%) after 6, 12 and 18 months after flooding relative to unflooded paddock
Months
6
12
18
Silt
Clay or Loam
Silt
Sandy

Farmer survey on the regrassing of silt

Introduction

In February 2004 the lower North Island was hit with the biggest flood seen in the region since 1902. Highest peak flows since recording began were recorded on the Whanganui and Whangaehu Rivers and third highest on the Rangitikei and Manawatu Rivers. Over a 36-hour period, 180 ml of rain fell, with the heaviest falls occurring in the Tararua and Ruahine Ranges and on the southern slopes of Mt Ruapehu which fed the upper catchments of the rivers. The multiple flooding of rivers in the region hit areas of Manawatu, Rangitikei, Horowhenua, Wairarapa and Wanganui the hardest. It was estimated that around 20,000 ha was inundated.

It was found that there was little published information on the recovery of flood affected pasture and what information was available was difficult to source. In addition, no systematic attempt had been made to collate farmers' experience and knowledge on regrassing flooded pastures. The focus of this report was to collect information from farmers post-February 2004 to determine the success or failure of strategies which were implemented. Information obtained from previous studies was also merged with the farmer information. This information will be condensed into farmer friendly documents that can be used as resource material in future flood events.

Method

Two farmer datasets form the basis of this report, firstly the Massey dataset collected from November 2004 to January 2005, and secondly, the AgResearch dataset collected a year later from January to May 2006. Where data in the result sections is specific to one data set it is indicated in brackets as (M) or (AgR).

Massey dataset: Farmers were selected from an initial short list provided by Federated Farmers from the Oroua, Pohangina, Manawatu, Rangitikei and Whangaehu but not the Rangitikei catchments. Further contacts were made by 'snowball' sampling where interviewed farmers recommended further contacts. Fifty-two farmers were interviewed and 110 cases were described. Verbal semi-structured interviews were conducted on the nature of silt and flooding, and regrassing and fertiliser strategies (Wilson and Valentine, 2005). For each case a site inspection was made by one person. An estimate of ground cover was made on two, 30 x 30 cm quadrats/case. Pasture was clipped to a standard 8 cm and photographed from a 1.5 m height vertically above the pasture. Green clover was estimated visually on quadrats using an eight point scale of percent cover. The eight point scale was judged using a photographic template that had been calibrated by pixel analysis for green/non-green colour. A soil profile was exposed to record sediment depth and presence and depth of anaerobic layers.

AgResearch dataset: Federated Farmers had compiled a database relating to the erosion and storm damage resulting from the February 2004 storm event in the lower North Island. In 2005, farmers who had indicated that they had flood damage on their farm were randomly selected from this database. Farmers that had already participated in the Massey survey were excluded and farmers were randomly selected. These farmers answered a questionnaire (Appendix) about the flooding, type and depth of silt, methods used to regrass silted paddocks, and fertiliser use for up to 3 areas on their farm. The 49 farmers reported on 91 blocks. They were asked to assess the recovery in DM production at 6, 12 and 18 months after regrassing. They were asked to indicate ongoing issues on flooded paddocks and recommend best practise.

Regrassed flooded areas

From January to May 2006 (mean date 3 March 2006), 46 of the surveyed farms were visited. A hole was dug to assess soil profile with respect to silt depth.

Silt profiles

In addition, two quadrats were placed on a representative area of each block on each farm. The percentage of vegetation type in terms of clover, and dead matter was assessed, then trimmed to 2 cm above the ground and photographed. The percentage of the quadrat area covered by green vegetation was estimated by eye. Image analysis of the photos was carried out to calculate the area of green cover within the quadrats. Visual assessment was used to estimate the percentage of dead matter and the combined result gave the total cover. The image analysis was checked visually (by eye) and, on occasion, over-ruled by visual assessment of ground cover.

Ground cover later assessed by image analysis

The survey results from farmers in the AgResearch database are presented graphically as means with 95% confidence intervals calculated using survey means procedures of SAS. The combined AgResearch and Massey datasets were analysed using analysis of variance and Chi-squared tests of independence. The data were also explored using discriminant analysis and multiple regression in an attempt to find combinations of factors that could adequately explain pasture grade, total cover, and green cover.

Results

Fertility of flooded sediments

The silt washed on to the land can either be fertile material from a farm upstream, or it can be subsoil washed from slips on steeper land. Soil tests can be taken in wet silt as the sample is dried in the laboratory. However, when the soil is wet less soil is collected per sample so more samples will be required. Sampling may be more challenging than normal. Also the drying process may result in lower Olsen Ps than would be obtained from a sample of dry soil.

At the time of the 2004 floods, Hills Laboratory provided free soil tests of silt for farmers, and the results are presented in Tables 1 and 2. Relative to normal soil, the silt had high pH, low organic matter, low P, very high sulphate, high base saturation and low P retention indicative of unweathered material probably of mudstone origin with little topsoil. There were differences between rivers and the Rangitikei River had generally more fertile silt, Oroua River silt was low in fertility and Manawatu and Whangaehu Rivers were intermediate. However, for practical purposes, with the exception of P retention, they were very similar and river differences would not impact on fertiliser recommendations.

Table 1: Mean, minimum and maximum values of 30 soil tests of silt collected within a few months of the 2004 storm.

Silt had high pH of 6.9, low organic matter of 1.6, low Olsen P of 8, very high sulphate levels of 27 indicative of largely unweathered material with little topsoil

Test	Mean	Minimum	Maximum
pH	6.9	5.8	7.8
Organic matter (%)	1.6	0	3.7
ASC P retention (%)	25.5	3	52
Olsen P (mg/L)	8.3	2	21
Base sat K (%)	3.0	1.2	5.4
Base sat Ca	75.7	55	94
Base sat Mg	15.2	4.5	29.1
Base sat Na	1.4	0.5	2.7
CEC (meq/100 g)	10.9	3	45
Base saturation (%)	88.7	2.1	100
SO_4S (mg/kg)	27.5	3	120
Organic S (mg/kg)	2.5	0.5	14.6
Available N (kg/ha)	33.7	1.2	103

Table 2: Mean fertility values of silt from different rivers within a few months of the 2004 storm event.

River	pH	ASC P retention	Olsen P	SO_4S	OM	Org S	Base saturation (%)						
							K	Ca	Mg	Na	Total	CEC	Avail N
Manawatu	6.8^{b}	19.8^{b}	8^{bc}	27.9^{b}	1.6	6.0	3.3	78.7^{ab}	14.9	1.1^{bc}		10^{a}	21^{bc}
Oroua	6.6^{b}	13.6^{b}	4^{c}	9.6^{b}	1.1	1.0	3.7	70.5^{b}	18.5	1.6^{ab}	94^{a}	4.3^{b}	8^{c}
Pohangina	6.7^{b}	19^{ab}	6^{bc}	34^{b}	1.1	2.3	3.0	74.5^{b}	15.0	1.0^{bc}	94^{a}	7^{ab}	26^{bc}
Rangitikei	7.3^{a}	29^{ab}	12^{a}	17^{b}	1.7	2.1	3.0	86.5^{a}	9.9	0.9^{c}	100^{a}	13.7^{a}	68^{a}
Turakina	7.7^{a}	28^{ab}	4^{bc}	36^{ab}	0.6	0.5	2.2	83^{a}	12.2	2.5^{a}	100^{a}	7^{ab}	13^{bc}
Waitotara	6.3^{b}	42^{a}	10^{abc}	73^{a}	2.8	1.8	2.5	56^{c}	16.7	2^{a}	77^{a}	11.5^{a}	25^{bc}
Whangaehu	7.2^{ab}	34^{a}	10^{ab}	24.2^{b}	1.5	4.0	2.8	75.2^{b}	16.1	1.5^{b}	95^{a}	13.3^{a}	38.4^{b}
P<	0.01	0.05	0.05	0.05	NS	NS	NS	0.001	NS	0.03	0.006	0.04	0.01

Bolded rivers contain two or less soil tests
P ret = phosphate retention, SO_4S = sulphate sulphur, OM = organic matter, Org S = organic sulphate.
Superscripts in the same column differ ($P<0.05$)

Fertiliser recommendations

Based on these soil tests, the flood sediment (unless mixed with topsoil) needs potassium and phosphate fertilisers with ongoing nitrogen. Phosphate, once dissolved from fertiliser, will not move far in the soil (unless the soil moves!) and rates of up to 1 tonne super/ha could be applied to raise Olsen P back to target levels. For example, if starting Olsen P is 10 then to increase this to 25 (for a dairy farm) requires 75 kg P/ha, either all at once or split as spring and autumn dressings.

Fertiliser recommendations for silt are potassium and phosphate fertilisers and ongoing nitrogen

Straight coarse sands near river channels are not suitable for large fertiliser applications. K should be applied to overcome a deficiency, i.e., apply 50-75 K kg/ha at each application and this may need to be done as a split application in autumn and spring. Due to the low organic matter and low available N, silt will have a continual requirement for drip-fed low rates of N, until the N cycle has been re-established (including soil organic matter). DAP with potassium chloride added could be a good fertiliser option but such recommendations should be on a farm by farm basis and in consultation with the fertiliser representative.

In any flood sediment that has been mixed with topsoil, urea is an appropriate nitrogen source. It is possible that in deep water-logged silt, urea may not be converted to a form that is useable by plants. In that case sulphate of ammonia may be a more suitable nitrogen source. Tests conducted at AgResearch on a sample of deep clay loam silt that was underwater for a number of weeks after the 2004 flood found reduced urease activity, but it's activity was still high enough to allow urea to be safely used as a fertiliser source. Given that urease activity is retained and soil sulphate levels are high, the ammonium sulphate is an expensive option for nitrogen.

Description of farms

Most of the AgResearch surveyed flood affected farms were intensive, small farms with deep silt. Massey surveyed farms by and large had shallow silt depths

Fifty-three percent of the surveyed farms (AgR) were located in Manawatu, 23% in Wanganui, 9% in Rangitikei, 14% in Horowhenua and 1% in the Tararua district. Thirty-six percent of the farms were totally flat with most of the rest flat/rolling but 18% had a flat/rolling/steep contour. The farmers categorised soil types of the flooded areas as predominantly recent alluvial or loess terrace soils. However, it is probable that along waterways the loess terrace soils were in fact recent alluvial soils unless the incidence of flooding was very infrequent.

Most farms (AgR) were pastoral (80% had more than 80% of land in pasture) though 11% also had arable cropping on their farm. Sixty-nine percent of the farms (AgR) surveyed were less than 100 ha, 28% were 101-250 ha and the remaining 3% were 250-500 ha. Forty-eight percent were dairy farms. Eighty-nine percent of the non-dairy farmers finished cattle, 22% bred cattle, 15% finished lambs, 12% bred sheep and 18% had areas of arable farming.

Flood and silt characteristics

In 75% of the farms surveyed by Massey there was little (<5 cm) or no sediment deposited, 24% had 5-25 cm of sediment and only 1% had deep sediment (>25 cm) on the land. It is probable that the time frame of sampling by Massey negated farmers with deeper silts as insufficient time had lapsed to allow resowing and grazing.

In the AgResearch dataset, in most cases the flooding rose above the resident, medium length, pasture, disappeared after a few days, and on 40% of the blocks more than 25 cm of silt was deposited (Figure 1). The mean depth of silt measured by the researchers (AgR + M) was 20.5 cm with 95% between 17-24 cm.

On farms surveyed by AgResearch, flooding mostly disappeared after a few days but average silt depth was 20 cm

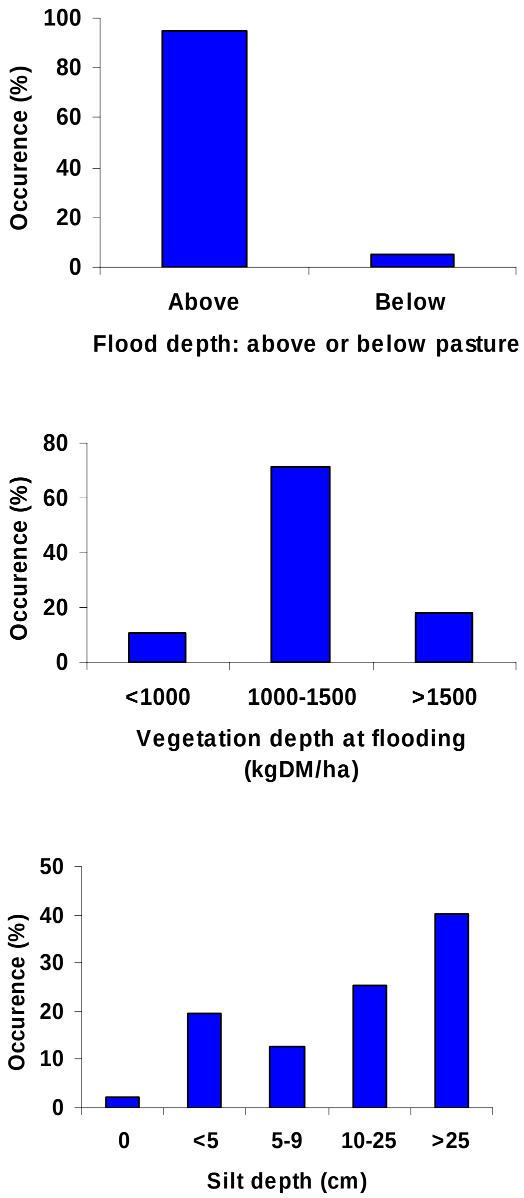


Figure 1: Description of the nature of flooding on the monitored blocks as recorded by farmers.

The silt (AgR) was predominantly sandy or loamy in texture but the flood deposition also included a lot of sand. Sixty-three percent of silt smelt off and this is indicative of ethylene gas, which is the result of anaerobic activity that can impede plant growth. Only 50% of silt deposits of 5 cm or less and 66% of deeper silt smelt. Seed germination after sowing directly on smelly silt can be impeded by the anaerobic toxins. However, recovery of the anaerobic silt following cultivation is rapid. In the AgResearch dataset no effect on production could be found to be associated with whether the silt was smelly or not.

Farmers also reported the presence of anaerobic layers produced by perched water tables months after the event. This was thought to be due to the buried organic matter found between the old soil and the new sediment.

Over half of the silt became anaerobic silt after the flood

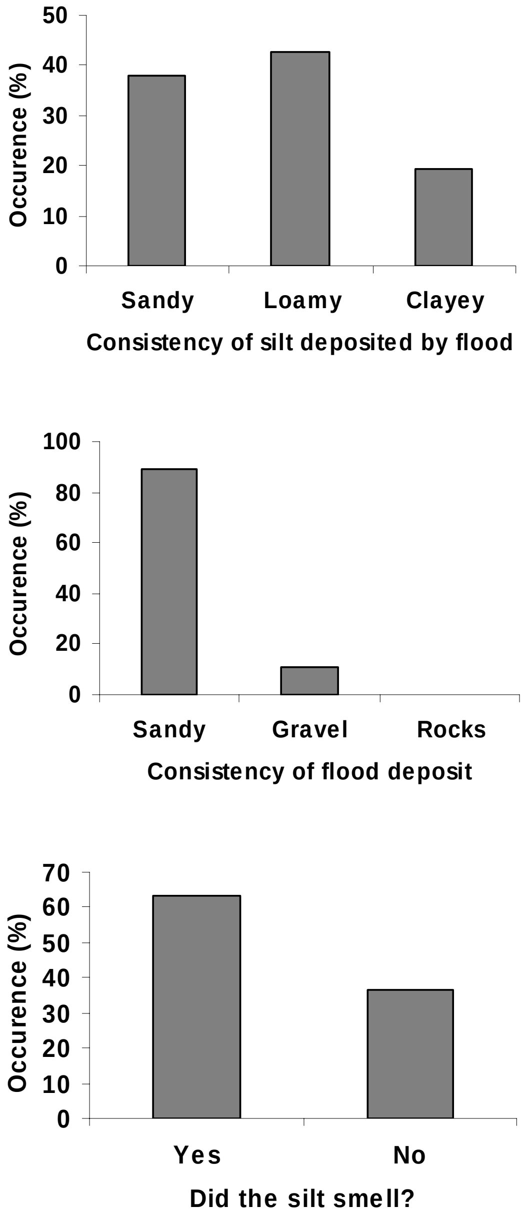


Figure 2: Description of the silt laid down by the flood.

Survival of resident sward

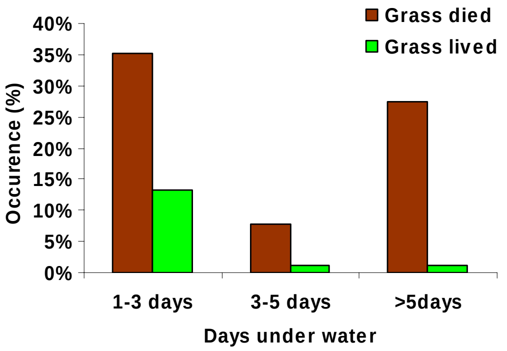
Overall the resident pasture died 80% of the time after flooding (AgR). High rates of survival of the resident sward occurred only when paddocks were under water for less than 3 days under shallow silt.

Research has found that recently-grazed pasture plants are more prone to silt and flooding damage than those with some regrowth on them. Pastures with leaf tips above water will survive, and subtropical grasses like paspalum will survive better than the temperate grasses most commonly grown on New Zealand farms. The grasses best suited to withstand deep siltation are grasses with rhizomatous spreading habits – couch and browntop. Creeping buttercup also tends to survive longer. Perennial ryegrass will only survive about a week, cocksfoot a few days longer, and tall fescue and timothy longer yet. Anecdotal evidence also suggests that Timothy and fescue do well on sandy silts in local accretion areas.

Flooding effects on pastures are worst when:

- Flooding occurs when soil temperatures are warm.
- A pasture has been hard grazed.
- Flooding is prolonged.
- Pastures are covered by at least 5 mm of silt.

(A)



Eighty percent of pastures died after flooding in the 2004 storm event

(B)

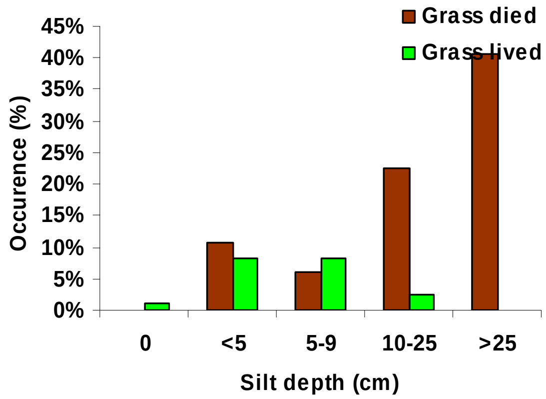
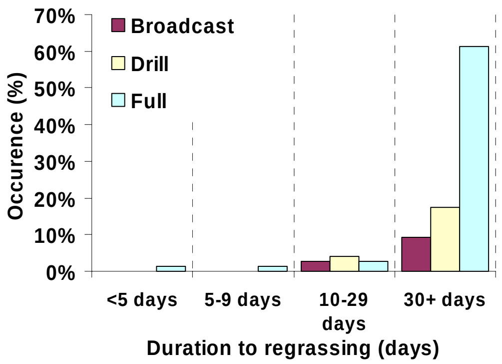


Figure 3: The effect of days under water (A) and silt depth (B) on survival of resident sward at the time of the flood.

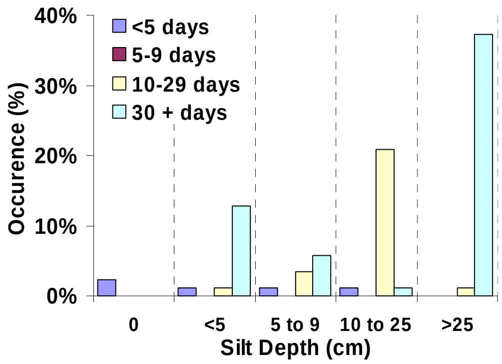
Duration to regrassing

In the Massey dataset, most pastures were sown by autumn 2004. In the AgResearch dataset, most paddocks were regrassed more than 30 days (maximum category on the survey form) after the flood event (Figure 4). This was largely unaffected by the method of regrassing with 78%, 81% and 92% of oversowing, direct drilled and full cultivated blocks respectively regrassed more than 30 days after the flood event. This was surprising because it was expected that direct drilling, and especially oversowing, would be more common methods immediately after the flood event while cultivation would be delayed. However, it was clear from the data that there was a delay in regrassing deep silt because of the difficulty of getting machinery on the paddock irrespective of the method used.

For most paddocks, even those oversown and especially those with deep silt, regrassing didn't occur until more than 30 days after the flood



(A)

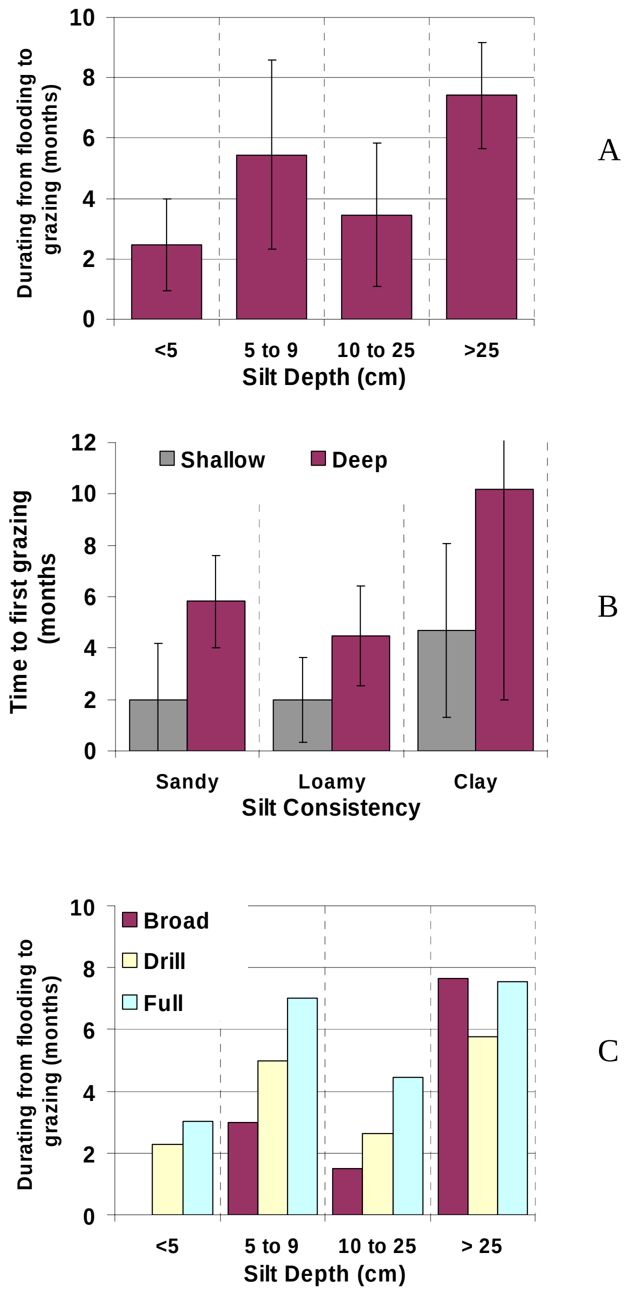


(B)

Figure 4: Effect on duration to regrassing of cultivation method (A) and silt depth (B).

Duration from flooding to grazing

The mean time (AgR) from the flood event to the first time the flooded paddocks were grazed was 5 months: 2.5 months for silt less than 5 cm, 3.5-5 months for moderate deep silt, and 7.5 months for deep silt (Figure 5). Grazing on clay silt was delayed by 2 or 4 months on shallow or deep silt respectively, relative to loamy or sandy silt. On all except the very shallow silt, full cultivation delayed the time to first grazing by about 2 months. Oversowing seed shortened the period to first grazing relative to full cultivation except on very deep silt (Figure 5).



The mean time from flooding to first grazing was 5 months. Fully cultivating paddocks delayed the time to first grazing by 2or more months. Time to graze clay silts was delayed by 3 months relative to other silts

Figure 5: Impact of silt depth (A), silt consistency (B) and method of sowing seed (C) on duration from flooding to first grazing. Error bars are 95% confidence intervals.
Two Figure 5s

Weediness of flooded paddocks

Massey dataset: Two patterns emerged with weed and pest problems. In areas where little or no sediment was deposited, weeds presented a problem. Plants with rhizomatous, below ground storage organs survived the flood well. Couch and creeping buttercup were cited by farmers as the main weeds. Strong germination of hairy buttercup, dock, mayweed and poa annua were commented on. The consensus was that these weeds were present before the flood and flourished under the conditions. Sediment deposits were regarded as clean by most farmers although there was a case of gorse germination in the Pohangina and lupins in the lower Manawatu.

AgResearch dataset: Farmers ranking indicated that weediness of flooded paddocks was an issue but it was only a moderate problem, possibly because 83% of farmers used some means of weed control after regrassing. Of the farmers controlling weeds, 86% had sprayed the paddock for weeds.

Weediness rankings were not affected by silt depth. The weediness score was higher for fully cultivated paddocks compared to direct drilled paddocks (Figure 6).

Flooded paddocks will require spraying for weed control as weeds present before flooding flourish

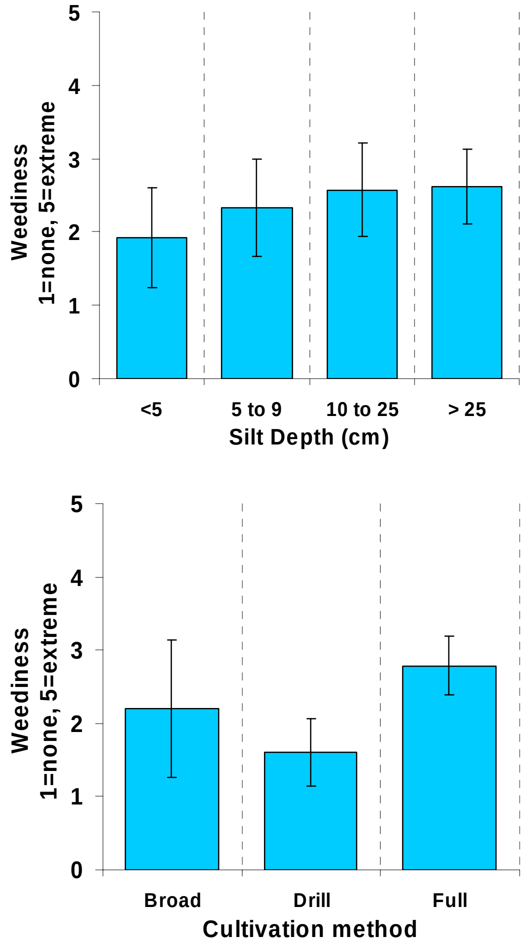


Figure 6: Weediness ranking of blocks by farmers for different silt depths and methods of cultivation. Error bars are 95% confidence intervals.

Subsequent production from flooded paddocks

Six months after the flood event, farmers (AgR) thought flooded paddocks produced 50% that of unflooded paddocks. For blocks with 25 cm or less, productive capacity was 55% but, on deeper silt, paddock recovery was only 40% (Figure 6). By 18 months these deep silts had recovered only 65% of productive capacity while shallower silts had regained more than 90% of productive capacity. Some farmers indicated that paddocks with shallow silt were slightly more productive than unflooded paddocks by 18 months. Fertile clay and loam silts were 20% more productive than sandy silts after 18 months.

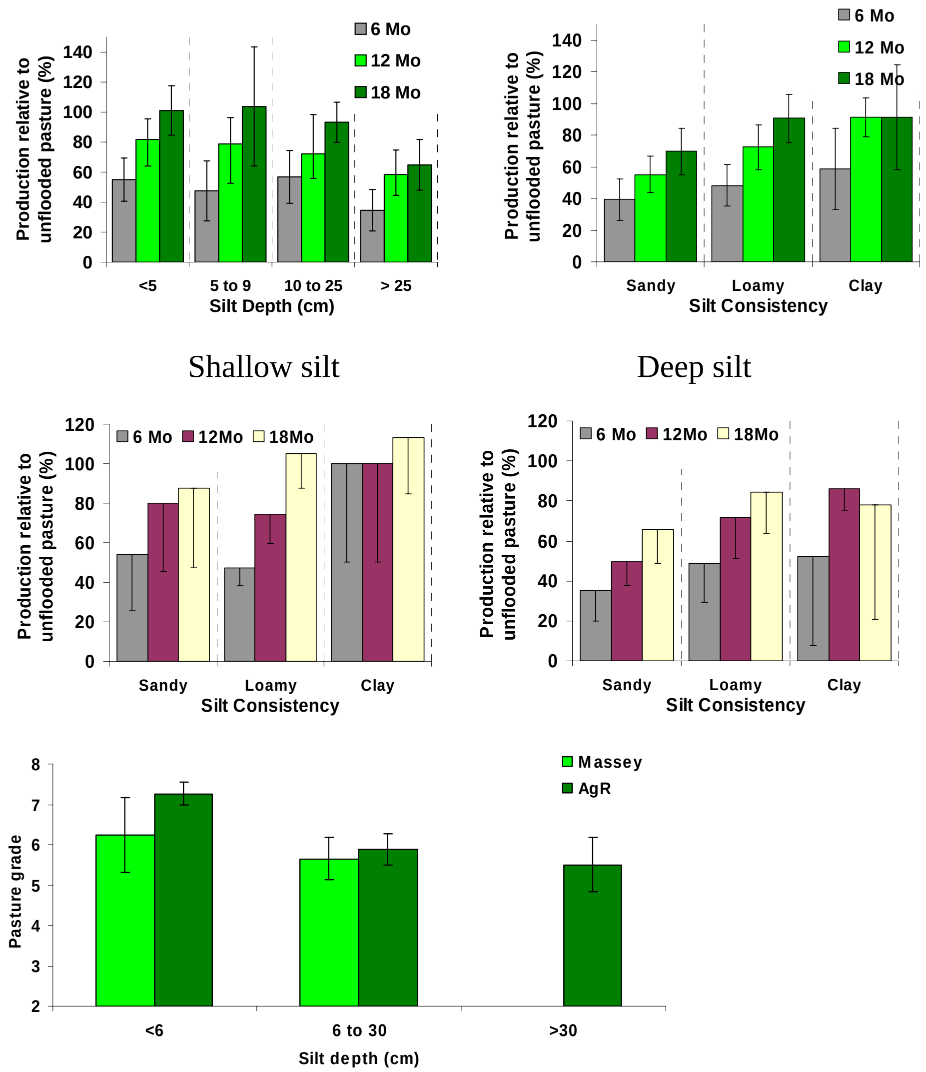


Figure 7: Farmer assessments of productive capacity of flooded pastures at 6, 12 and 18 months on different silt depths and different silt consistencies, and their combinations, after the 2004 flood event; and Massey (10 months) and AgResearch (22 months) researchers' grade on pasture cover. Error bars are 95% confidence intervals.

According to farmers, deep silt produced 50% and 35% less than unflooded paddocks 6 and 18 months after the flood. Fertile clay and loam silts were 20% more productive than sandy silts after 18 months

Researcher-assessed production: Massey and AgResearch researchers visually graded (1-8) the flood affected paddocks for green ground cover at 10 and 22 months after the flood event. AgResearch data showed that ground cover on deep silt was 25% lower than on shallow silt after 18 months. In the combined dataset, the shallowest silt had the highest pasture grade score (P<0.001).

Regrassing method

The regrassing method was defined in three ways for analysis:

1. Mixing of silt with topsoil was divided into 2 categories, minimal (MIN) or fully mixed (FULL).
2. The method used to sow the seed, which was also associated with different mixing of topsoil, was divided into 3 categories:
   Broadcast/oversown + no mixing of topsoil = oversown
   Drilled + no mixing of topsoil = direct drilled
   Sown during full cultivation = full cultivation

3. The method of sowing the seed irrespective of topsoil silt mixing, namely direct drilled, cross drill or broadcast, all of which can be used in any combination of topsoil mixing.

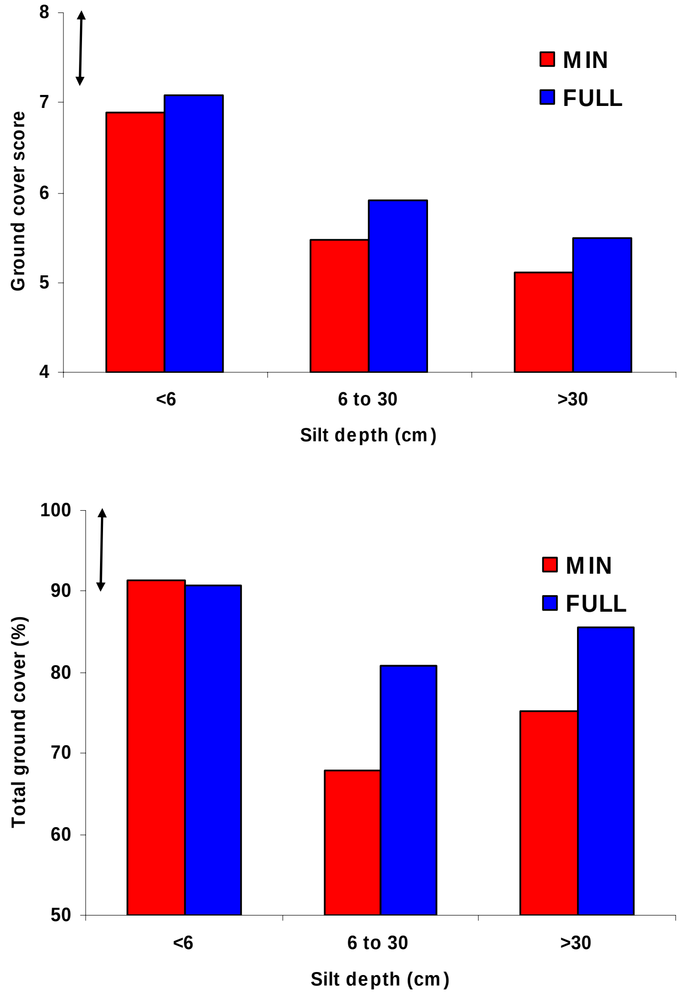
Statistical differences were found between different methods but the amount of variation described in ground cover by different regrassing methods was small (around 20%) in both datasets.

1. Mixing silt and topsoil: minimal vs full cultivation

The combined AgResearch and Massey databases had 198 blocks classified into either minimal or full cultivation. The mean number of passes for fully mixed (FULL) was 3.2 and for minimal mixing (MIN) was 1.2. The split between FULL:MIN was 60:40 and 28:72 for the AgResearch and Massey databases respectively. This confirms that the Massey researchers largely surveyed farms with shallow silt. In both databases the split was around 50:50 between MIN and FULL in each silt depth category: <6 cm, 7-30 and >30 cm.

In the Massey database collected at 10 months after the flood event, the FULL blocks had a higher ($P<0.002$) pasture grade score (6.7 vs 5.7) and this persisted ($P<0.02$) in the combined databases (6.3 vs 5.9). This difference was also found in total ground cover in the AgResearch dataset ($P<0.02$) where the interaction with silt depth ($P = 0.10$) was also more apparent, indicating that mixing of topsoil is less important when plant roots can reach through into the topsoil (Figure 8). At silt depths of greater than 6 cm, mixing the topsoil with the silt improved total ground cover after 2 years by 16% relative to non-mixing.

Mixing of top soil and silt is recommended where possible because silt is relatively infertile, will contain no organic matter or N, and have poor structure making it prone to pugging. A barrier to water drainage may occur on the interface between the old pasture and silt. It is better in the long run to cultivate the deeper deposits so the silt and topsoil are combined. However, if the silt is very sandy it may be more appropriate to remove the sand first, if this is possible. There will be a cost in time taken waiting for the silt to dry out sufficiently to allow full cultivation. If the silt is too deep then it will be impossible to mix topsoil with silt.



Mixing of silt and topsoil improved ground cover in flooded paddocks on deeper silts by 16%. Where pasture roots could reach the topsoil this difference was greatly reduced

Figure 8: Impact of mixing silt with topsoil on ground cover grade during regrassing (from the combined datasets, or total ground cover in the AgResearch dataset). Arrows represent average least significant differences.

2. Method of sowing seed: oversow vs direct drill vs cultivation

The 115 blocks were categorised by the method of sowing, namely oversown (no mixing of silt and topsoil), direct drilled (no mixing of silt and topsoil), or sowing during full cultivation, and the relative proportions of each method were 16%, 37%, 47% respectively. The Massey dataset contained proportionally more direct drilled than fully cultivated paddocks than the AgResearch dataset. As silt depth increased proportionally more paddocks had seed oversown and less were direct drilled but the proportion of fully cultivated blocks remained relatively constant across soil depths (Figure 9).

Oversowing was more common and direct drilling less common on deep silt

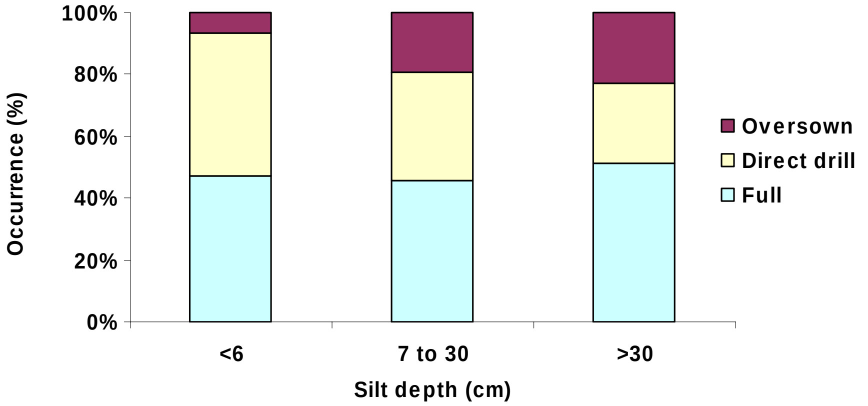


Figure 9: Proportion of blocks within various silt depths that were oversown, direct drilled or fully cultivated.

Farmers indicated that production of paddocks following drilling was slightly better than full cultivation at 6 months, similar at 12 months but inferior at 18 months (Figure 10). Broadcast seed initially performed well but was less productive over the long term (Figure 10). Interestingly, by 18 months farmers ranked the fully cultivated paddocks on all but the deepest silt as productively superior to unflooded paddocks (Figure 10).

At six months farmers assessed oversown paddocks as performing 30% better in the short term but 30% lower in the long term compared to fully cultivated paddocks with moderate silt depths

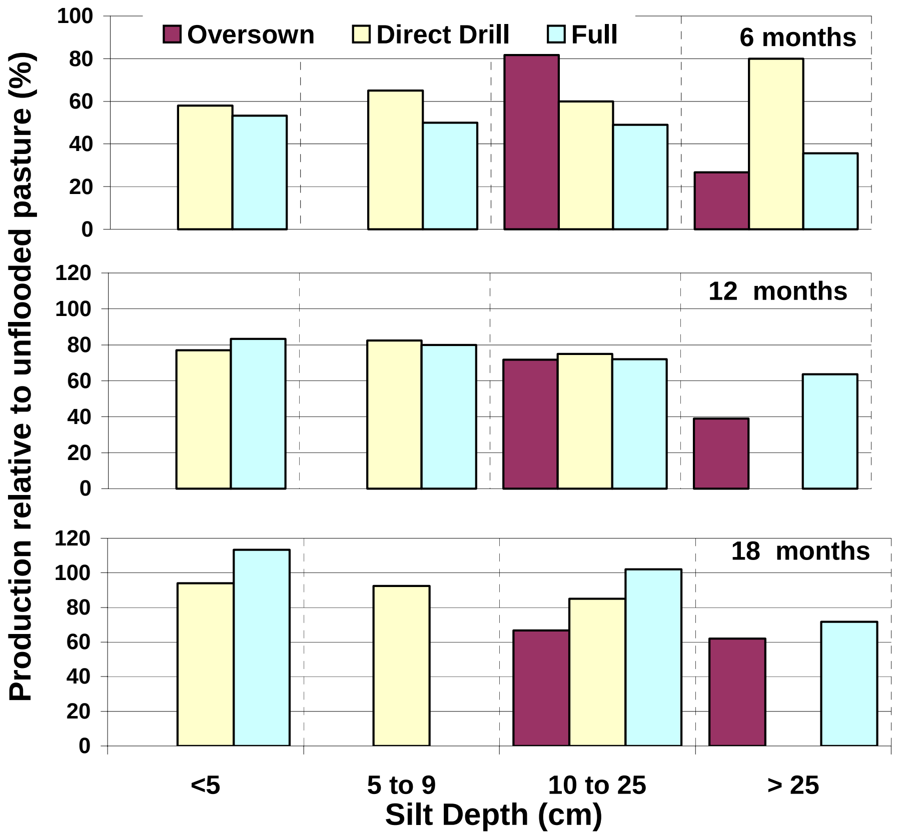
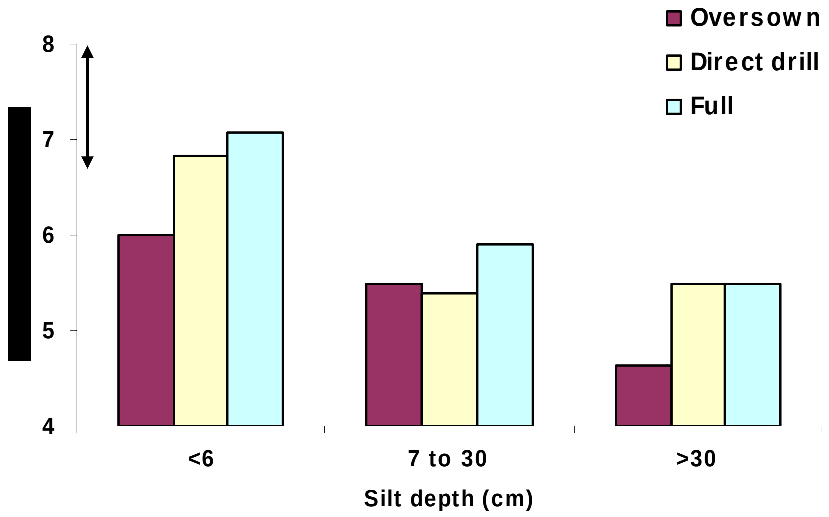
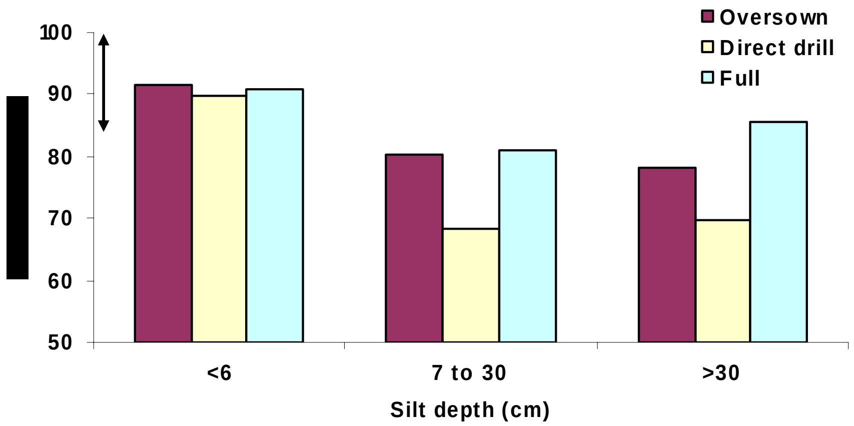


Figure 10: Productive capacity relative to unflooded paddocks as assessed by farmers on blocks with varying silt depths and different methods of regrassing (broadcasting seed, direct drilling or full cultivation).

Ground cover score was lower (Figure 11) on pastures that were oversown (P<0.002) compared to direct drilled or fully cultivated pastures. This mainly occurred in the Massey dataset comprising shallower silt but less with the AgResearch dataset (P<0.01) (Figure 9B). In the AgResearch dataset (Figure 11B), measures of total cover showed that the direct drilling of seed on deeper silt was less effective (P<0.04) than other methods of seed application (Figure 11B). The poor results from direct drilling in deep silts were probably because this technology depends on good soil structure to stabilise the slot.



(A)



(B)

Figure 11: Ground cover score (A) or total cover (AgR) (B) on paddocks where seed was applied during full cultivation, by direct drilling or by oversowing on different depths of silt. Error bars represent average least squares difference.

From past flooding events such as Cyclone Bola, farmer experience and research indicates that oversowing is not an option for sandy silt but is an option to consider for clay/silt loams. Oversowing needs to occur when the silt is still damp and sticky (birds won't land) and must occur quickly once water has receded. Once the silt has caked and cracked it is too late for oversowing because grass plants will struggle to grow and seeds may blow away or be eaten by birds. Relying on rewetting the silt after rain to foster germination of oversown seed is unlikely to work. It is recommended to use coated, good quality seed to increase its chance of establishing and improving ballistics. If clover is included in the mix, use inoculated seed (at very little extra cost) that also contains molybdenum. There were insufficient examples of the recommended practise (e.g. coated, inoculated) in the farmers' dataset to assess success. It is probable that after oversowing deep silt, full cultivation would subsequently be needed.

3. Method of sowing seed

Seed was sown by broadcasting, direct drilling and roller drilling during minimal or full cultivation. A roller drill was the choice of seed sowing for 60-80% of farmers fully cultivating paddocks irrespective of silt depth. Under minimal cultivation on shallow silt, direct drilling was the method of choice for sowing seed 60% of the time. On deep silt, farmers using minimal cultivation were equally split between those sowing seed by broadcasting seed or drilling with a roller drill (Figure 12).

Farmers chose to use roller drills to sow seed if silt was fully cultivated. Under minimal cultivation, the method of seed sowing changed from direct drilling in shallow silt with less direct drilling and more roller drills and broadcasting as silt depth increased

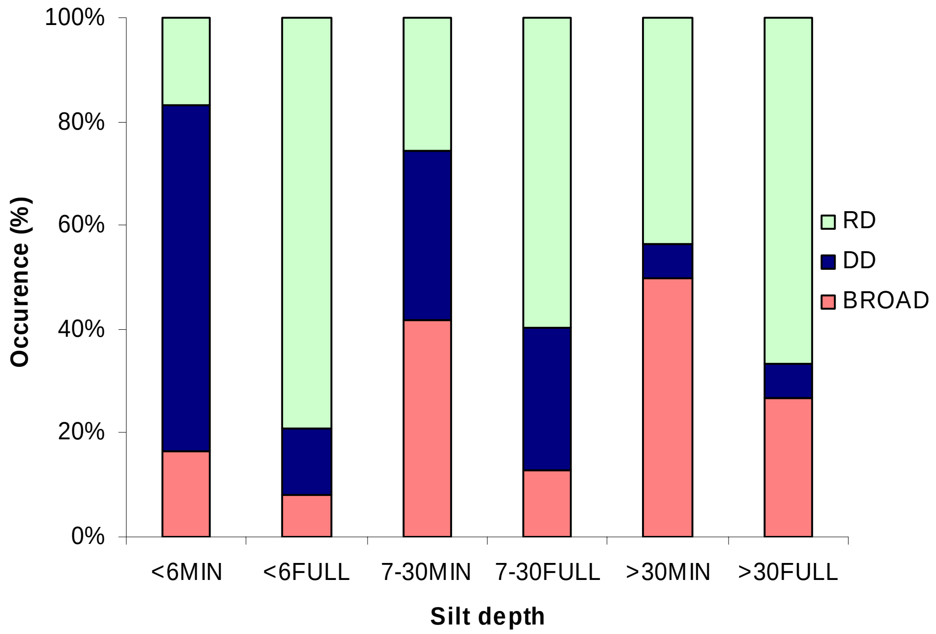
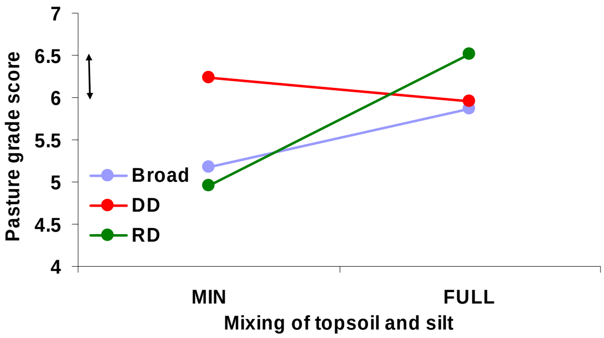


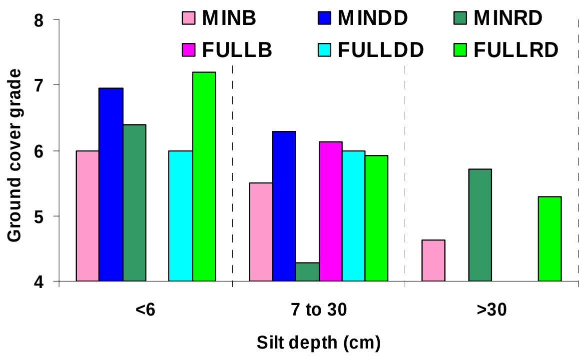
Figure 12: Occurrence of different methods of sowing seed: roller drill (RD), direct drill (DD), broadcast (BROAD) with minimal (MIN) or full (FULL) mixing of silt at varying depths of silt (<6, 7-30, >30 cm).

Overall, full cultivation increased ground cover score by 9% ($P<0.002$) and there was a strong interaction with the method of sowing seed ($P<0.0001$) as shown in Figure 13A. A roller drill was less effective when it was used under minimal cultivation compared to full cultivation, with the difference largely expressed on intermediate silt depths (Figure 13B). In contrast, a direct drill was a less effective method of sowing seed when used in association with full cultivation especially on the shallow silt deposits.

Silt depth is the main determinant of ground cover. Unfortunately there are insufficient data points to look at all three interactions (silt depth/seed sowing/silt mixing) statistically. Means are presented in Figure 11B where cells contain 5 or more measurements.



(A)



(B)

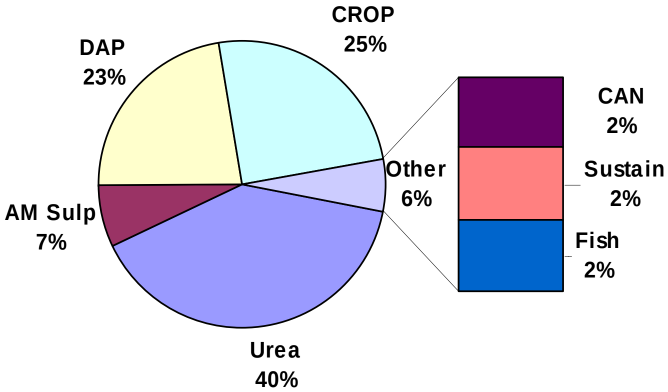
Roller drills were less effective and direct drills more effective on minimally cultivated silts compared to fully cultivated silts

Figure 13: Mean ground cover score for combined datasets not differentiated by silt depth (A) or differentiated by silt depth (B) on regrassed paddocks sown by broadcasting (B), direct drill (DD), or roller drilling (RD) on seedbeds with minimal (MIN) or full (FULL) mixing of topsoil and silt.

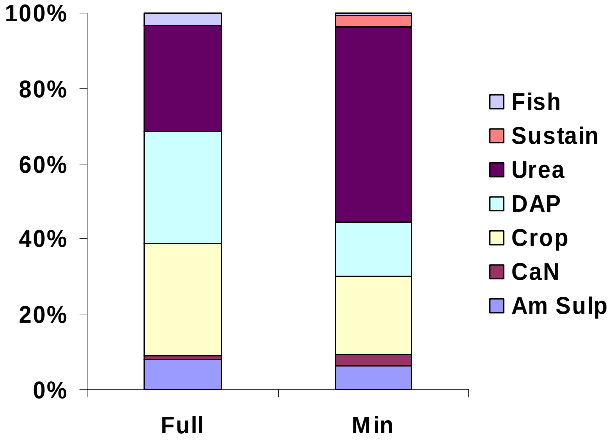
Fertiliser use

The combined database contains 153 records of the source of N on blocks at first application. The most common sources of N were urea, DAP (straight, 13S, 15S) and Crop (Master, zeal, 15, 20, 21) (Figure 14). There was no difference in the sources of N used on different depths of silt. Under minimal cultivation, urea was more common, comprising 52% of the N used at first application (Figure 14)

Urea was the most commonly used source of N particularly on paddocks that weren't cultivated



(A)

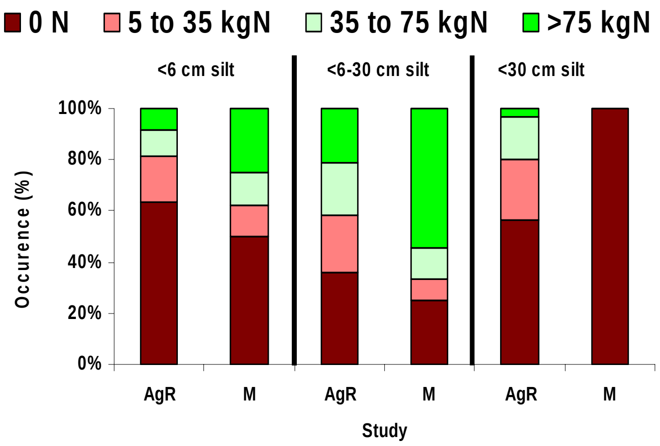


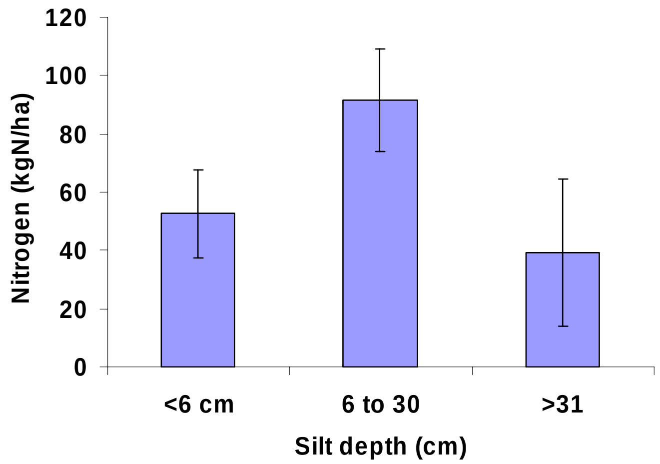
(B)

Figure 14: Types of fertiliser used overall (A) and broken down in FULL and MIN seedbed preparation (B).

No N was put on to 48% of flooded blocks in the AgResearch dataset and 23% of the Massey paddocks. It was more common for farmers not to use N on shallow silt and very deep silt compared to the medium ranges of silt (Figure 14).

Of the farmers putting on N, the average accumulated rate of N applied to silt damaged pasture was 90 kg N/ha: 64 kg N/ha in the AgResearch dataset (22 months after the flood) and 105 kg N/ha in the Massey dataset (10 months after the flood). Farmers put around 40 kg N/ha more N on the medium silt depths compared to shallow silt or deep silt ($P<0.004$) in both the AgResearch and Massey datasets (Figure 15B).





Some farmers didn't use N on flooded paddocks and 40 kg N/ha more was used on medium silt depth paddocks compared to shallow and deep silt

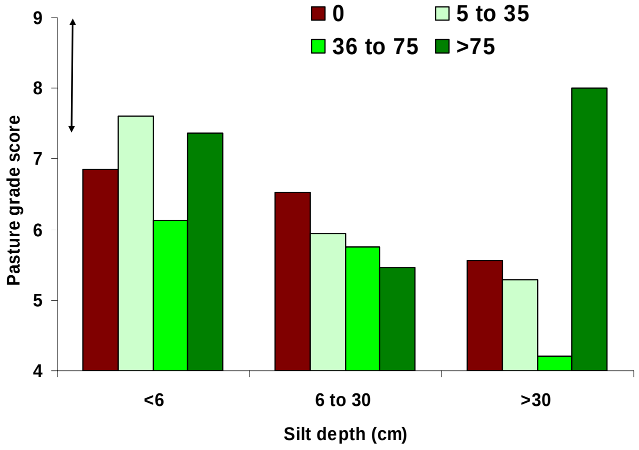
A B

Figure 15: Occurrence of various rates of N applied to flooded paddocks in the Massey and AgResearch datasets (A), and where farmers used N the mean rates of N applied to various silt depth (B). Error bars represent 95% confidence intervals.

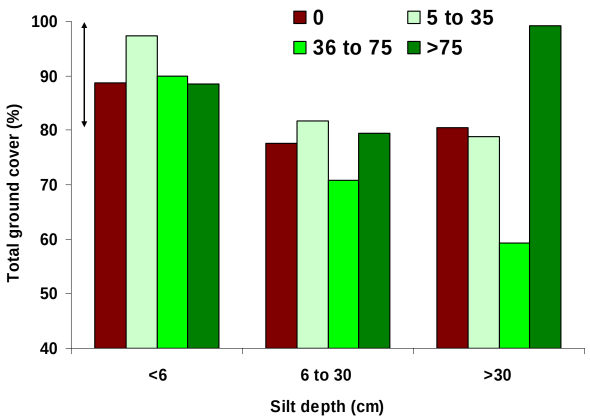
After N was grouped into zero, low, medium and high N application rates, no effect could be found of N on pasture grade score (combined database) or total cover (AgR) (Figure 16). This data is likely to be biased because farmers chose a rate of N they thought the paddock needed so paddocks showing more extreme signs of N deficiency may have received more N and this biases the data. .

After the March Cyclone Bola storm, silts (silt fertility very similar to 2004 storm) of more than 1 m were oversown in a variety of species in April and had 0, 150, 300 kg of DAP applied. Dry matter production was increased by the two rates of DAP by 30% and 40% respectively (Gray and Korte, 1990).

No statistical effect of N use on ground cover could be found



A



B

Figure 16: Pasture grade score (A) in combined database and total ground cover (B) in AgResearch database in paddocks receiving no, low, medium and high rates of N.

Deep silt with no N applications had clover over 20% contents

Clover content of pastures was 13% in deep silt compared to 5% in medium and shallow silt (P<0.05). Clover content was lower in silt receiving low and medium rates of N compared to no N or very high levels of N (P<0.04). However, most of this effect was due to the very high level of clover content on deep silt receiving no N (P<0.05) (Figure 17).

Research results indicate pasture growth rate on silt increases by 30-40% when fertiliser is applied

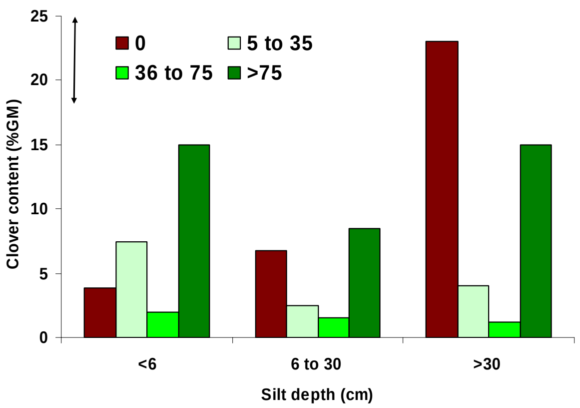
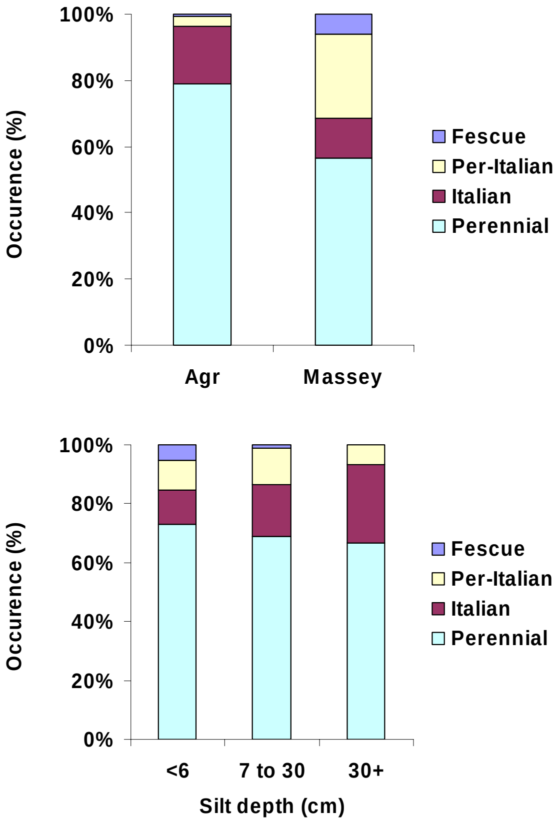


Figure 17: Eye-assessed clover content of pastures in the AgResearch dataset.

Pasture species

Farmers predominantly sowed perennial ryegrass, more so in the AgResearch dataset than the Massey one (Figure 18A). There is a small tendency to sow more Italian ryegrass on deep silt but the differences were not large (Figure18B). This has been recommended as best practise because it gives two cultivation opportunities on deep silt which, in conjunction with grazing, can help build up organic matter in the soil. However, few farmers took this option presumably because they believed the double cultivation costs were in excess of any potential benefits. There was no tendency to use different rates of fertiliser for difference species.

Most farmers sowed silt with perennial ryegrass clover mixtures



A B

Figure 18: Occurrence of use of different species of grass in the two datasets (A) and at different silt depths (B).

Very little information can be obtained on clover as 61% of farmers simply said that they sowed clover with a further 34% sowing large leaf clovers, 3% medium leaf clovers and only 1% sowed red clover. A few farmers included plantain and chicory in some mixes but the number of farmers who did this was too small to warrant analysis.

The predominant grass species sown was perennial ryegrass (Table 3) so the number of other grass species used was small. The Massey dataset showed no effect of pasture species on ground cover. The combined datasets showed that the pasture cover score from fescue was higher than perennial and hybrid ryegrasses while annuals were lower. Only Italian and perennial diploid ryegrasses were sufficiently represented across silt depth classes.

Pasture grade (P = 0.13) and total cover (<P<0.01) data showed that Italian ryegrass did worse on intermediate and deep silt than did perennial ryegrass (Figure 19). It is not surprising that the annuals had lower ground cover because they are normally less dense than perennials and, in the time frame of the measurements, annuals would be either running out or had been recently regrassed. However, annuals are also more demanding on soil fertility. The farmers (AgR) also indicated that annual grasses performed more poorly on the deeper silts than perennial grasses.

Research conducted after Cyclone Bola on oversown deep silts found that dry matter production 5-6 months after sowing was 55% higher for Moata, an annual ryegrass, compared to Droughtmaster, a perennial ryegrass adapted for survival under adverse conditions. However, the difference in performance between the annual and perennial grasses is likely to converge with time.

Table 3: Occurrence, ground cover grade, total cover and proportion of clover (%) for various species of grass following regrassing silt.

	Italian		Perennial + Italian		Perennial		Fescue	LSD	P<
	Diploid	Tetraploid	Diploid	Tetraploid	Diploid	Tetraploid			
Common	Annual	Annual	Hybrid	Hybrid	Normal				
Occurrence (%)	7	7	13	3	59	7	4%		
Ground cover grade	4.9	5.4	6.4	5.1	6.1	6.4	7.2	1.2	0.001
Ground cover grade	5.1		6.1		6.1		7.2	1.0	0.001
Total cover (%)	76	75	100	87	82	61	na		
Clover (%)	1	8	15	2	11	4	na		

Annual ryegrasses may have performed poorly on the intermediate and deep silts

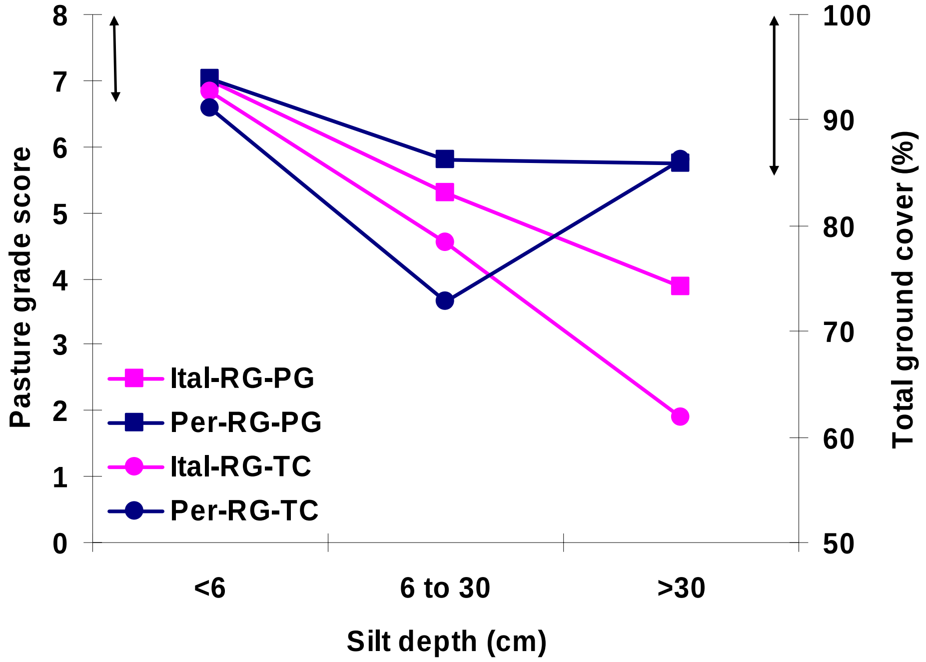


Figure 19: Effect of use of perennial versus annual grasses on ground cover score and percentage at various silt depths.

Alternative species

Crops performed well on silts but the recovery of organic matter in silt is a slow process

After the February 2004 flood, the role of alternative species in rehabilitating organic matter in silt was examined (Brock and Douglas, 2006). This study was conducted on 20-50 cm silt deposits from the Pohangina River. A range of plots was sown by hand followed by a light harrow. Species examined were Rahu ryecorn (sowing rate 110 kg/ha), Massif oats (130 kg/ha), Feast II Italian ryegrass (33 kg/ha), vetch (165 kg/ha), Balansa clover (13 kg/ha), or a pasture mixture (33 kg/ha of Pacific perennial ryegrass, Tekapo cocksfoot, Maru phalaris, Choice chicory, Tahora white clover, Bounty white clover and Leura subterranean clover).

Two months after the February 2004 storm, half the plots were grazed and half were allowed to grow to harvest and then were cut for yield determination with material returned to the plots. In the cut only group, lupins were substituted for pasture. From May 2004 to November 2005, 158 kg N/ha, 102 kg P/ha and 50 kg K/ha were applied, split over five dressings. Germination of species was good. Six months after sowing, the yields on the cut plots were 7310 kg DM/ha bitter blue lupins, oats 6125, ryecorn 5830, annual ryegrass 5525, vetch 5445, and Balansa 5410 kg DM/ha.

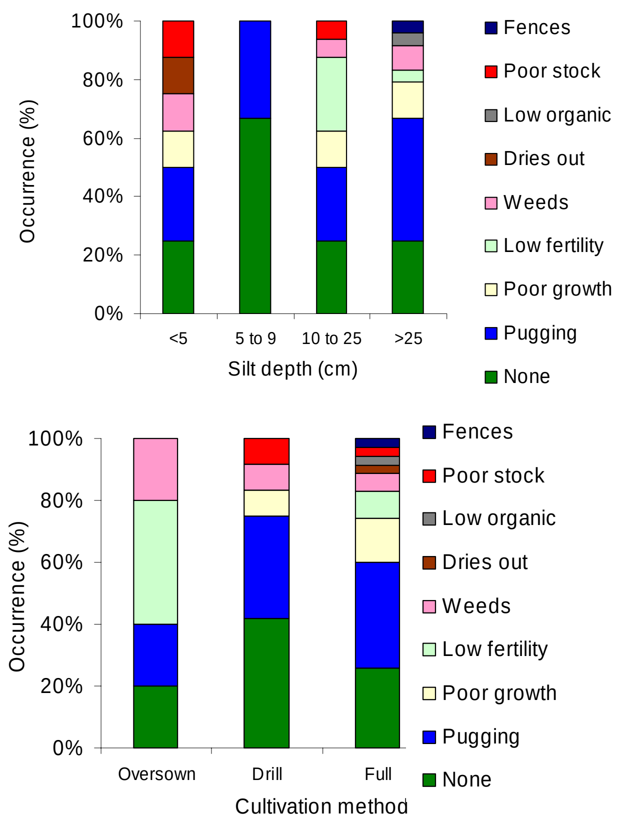
Two years later, the fertiliser regime had increased – Olsen P from 5 to 32 and soil K from 2 to 8. There had been a five-fold increase in organic matter (<0.1 to 0.5% OM) and a 2.5-fold increase in C:N ratio (5 to 12.5), but values were still much lower than optimal for a healthy soil. These increases were slightly higher in the grass-based series (oats, ryecorn, ryegrass) than the legume (vetch, Balansa, lupin/pasture). Soil organic matter was similar in cut and grazed swards. In pasture swards the clover died out over the next summer due to drought.

Ongoing farmer issues

After regrassing flood affected paddocks, 70% of farmers (AgR) indicated that they had ongoing issues with the paddocks. Of these farmers, the most common issue was pugging and poor drainage and this was an ongoing problem for 50% of the farmers. Pugging was an issue on all silt depths following all cultivation methods (Figure 20). Low fertility was a more common issue in oversown paddocks and paddocks with deeper silt depths. Weeds and poor pasture growth were also ongoing issues. It was also interesting to note that a few farmers had issues with poor stock performance.

Poor drainage and pugging damage is an ongoing problem on flooded paddocks

A.



B

Figure 20: Farmers indication of ongoing issues with regrassed flooded paddocks for different silt depths (A) and different cultivation methods (B).

Best practice

Farmers in the AgResearch dataset were asked their opinion on the best practise for regrassing silt affected paddocks. The greatest consensus came with 50% of farmers indicating that whenever possible the silt should be mixed with the topsoil. After that, farmers' opinion was split between hurrying and getting seed on to the paddock and waiting for the silt to dry and cultivating the paddock, with more indicating waiting for the silt to dry was the best option (Table 4). Drilling was popular with a small proportion of the farmers as was using a crop/annual step in the regrassing process.

Results discussed for best practise for regrassing paddocks clearly depends on silt depth. Other factors will include cost of the regrassing practise, impact of regrassing method on time to regrazing, and relative effectiveness of various regrassing practises in the short and long term. Farmers also need to consider feed supply issues relative to feed demand over time which will be affected by the proportion of the farm affected.

Table 4: Farmers recommended best practise as a percentage of 45 replies.

Farmers recommend mixing topsoil and silt together where ever possible

Issue	Farmers recommended best practise (%)
Mix silt with topsoil	50
Direct drill if can	15
Don't rush and do it right	13
Get on to it quickly	7
Annuals	4
Crop before regrassing	4
Do nothing	2
Don't rush stock on	2
Spray thatch	2%

Farmer commentaries

Flooded again – by Mike Hoggard, farmer

The 2004 flood saw 60 ha flooded but 12 ha of this area in particular was left with 0.5 to 1 m of a sandy and rubble deposit (see photo below).

As the area had only a thin 5 cm layer of topsoil, having previously been flooded during the Cyclone Bola event, it was deemed neither practical nor possible to successfully remove the sand.

The decision was made to crossblade the area with a 27 ton bulldozer, moving first the wood, trees, and rubble to add to an existing bank, then levelling the sand and silt, covering the rubble and leaving a paddock capable of being cultivated. Over the line where we buried the rubble we built a new stock race.

The area was sown down with a mixture of Moata and clover and heavily fertilised. We treated the area as basically a hydroponic area that relied on fertility bought in.

We have since direct drilled in Pacific rye which was recommended as suitable for low fertility and a challenging environment.

The aim is to allow a topsoil to be recreated through stocking and resowing regularly with grasses suitable for these challenging conditions.

What we have found is that grass production decreases each year and requires regular renewal. (In another area we found that the clover flourished swamping out the permanent grass that was sown.)

During the winter, the dry cows are on this area for 2-3 hours per day while their supplements are fed to encourage a transfer of organic matter.

Dealing with different types of silt – by Mike Webster, farmer.

After the February 04 floods I've found we were dealing with different types of silts. Close to the Turakina River, which flows through our property, we had a layer of coarse sandy silts very much like being on a beach. Further back from the river in areas where the river had spread out over the flats but away from any real current we gained what we came to know as "ponding" silt.

The coarser sandier type of silt near the river was 1 m+ deep and covered a very good crop of potatoes. It took a long time to dry out in places and three months later was still unable to support the David Brown 990 in a lot of places. There was at the time a crust of about 18 inches of dry ground on top but if you broke that it was still wet and porridge-like underneath. Because of this we decided to work the ground closer to the river with the sandier types of silt with the 4WD quad. We towed two plates of tyned or Dutch harrows around to scarify and work up the surface. At one stage we tried three plates of these harrows but found them too hard to pull with the 450cc bike and the motion of the harrows caused a vibrating action that was too rough on the bike as well.

As soon as that was done we went straight on with the ATV-towed spinner and sowed the seed which in our case was good quality rye clover mix using coated clover seed at 35-40lb/acre. Immediately after that we used the "Brush Harrow" basically a 4x2 across the back of the bike with kanuka heads tied to it and literally brushed the seed in.

A word of caution here: whilst most spreaders on the market spread fertiliser quite adequately, not all spread grass seed well. In our experience the better types have an agitator closer to the base of the hopper and at least two slots or outlets preferably well apart. The reasoning behind this being on some models or brands the admitter is too far away from the base and there is not enough seed movement causing or allowing seed, especially rye, to bridge and block the slots. In some lights or conditions it is hard to pick up on the fall or throw of seed.

By contrast we were able to get machinery onto the ponded silts. This was because most of it was only 1 ft deep and its plasticine type of texture meant that when it dried out it would support our 100HP tractor and rotary hoe. This meant that in a lot of areas we were able to blend some of the silt with the ground it had covered. For the sake of the tyres and rotary hoe every effort should be made to get any obvious debris out of the ground especially ¼ round posts! We also sowed this area with a spinner but found the brush harrows didn't work as well on this type of soil so we used a light set of chain/grass harrows. Because of this blending action on this country we sowed a permanent pasture type of mix and it still persists today.

Prior to working up the silted country we had it soil tested – both types showed a high pH, no organic matter and Olsen P of 6-8. Following sowing we applied urea at 40 kg/ha. We did this three times and had a good response, applying fertiliser as soon as the plants appeared to be under stress, in our case the ryegrass would go brown at the base. The urea was phased out in favour of crop 15 at the same rate and all country is now back into a regular top dressing programme. By the autumn of 06 we had a sufficient pasture base to break feed and use as a wintering pad on a main block of 12 ha.

By August 07 the ponding silts had recovered to be ordinary pasture. However, the deeper sandier silt country appears to have run out and recent grazing with cattle has caused tufts of turf to be pulled out. This spring I plan to "skim" plough, lightly disc, resow and roll the area (12 ha). This process I hope will start to build a layer of organic matter and will I hope in time provide a better growing environment.

The older farmers in the valley who have experienced this sort of flood damage work on a 15-year regeneration time frame. As well as grass some also use lucerne and maize as part of the process, the latter whilst requiring large amounts of fertiliser appears to build up valuable organic matter and adds to soil structure when ploughed back in.

It's not a fast process but this sort of silting is salvageable and in many cases is just part of a process that has been going on over hundreds of years

Useful references on flooding and silt regeneration

Boswell, C.C.; 1979. Effects of flooding on pastures and crops – A review; Technical Report 6; March 1979

Boswell, C.C.; Flooding in pastures and crops – Plant tolerance and survival and effects on soil nutrients; Agricultural Science and Technology (MAF)

Gray MH and Korte, C.J.; 1990. Revegetation of river silt deposits. Fertiliser and lime report.

Harvey, Tim; Damage assessment codes – Massey University; 18/2/04

McKee J.G. and Graham G.J.; 1952. Pasture establishment on flood areas of Gisborne flats. New Zealand Journal of Agriculture 84: 197-198.

Wilson M.D and Valentine I., 2005. Regrassing flood-damaged pastures. Proceedings of the New Zealand Grassland Association 567: 117-121.


Resene