Slip recovery
Southern North Island Storm Event 2004

Lower North Combined Provincial Federated Farms Storm Group
SUSTAINABLE FARMING FUND: PROJECT 05/060
Meat and Wool FITT project

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FEDERATED FARMERS OF NEW ZEALAND (INC)
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Executive summary

Eighty one farmers were asked to describe the effectiveness of their previous soil conservation practises on the prevention of slips following the February 2004 storm event. They also described their slip revegetation practises and their perception of the success or failure of these practises. Students later visited slips on each farm to assess by eye the pasture composition and ground area. They took photos of the pasture on the slip scarp, middle and tailings as well as of the adjacent undisturbed ground. These photos were assessed for ground cover using image analysis.

Three quarters of the farmers reported that less than 10% of their farm was affected by slipping after the storm event of February 2004. Mudstone and sandstone soils were worse affected. Individual farmers found predicting the pattern of slips difficult with little consensus between farmers of key risk factors, apart from steepness.

Nearly all farms had densely treed areas but these commonly occupied over less than 10% of their land area. Farmers considered that their tree plantings were only partially effective at preventing slipping during the storm event. The dense planting of older trees in areas retired from grazing were considered by farmers as the most effective at preventing slipping. Despite this few farmers intended to retire further areas. In fact, space planting poplars was by far the most popular practise farmers intend to implement in the future for reducing slipping.

Farmers who regrass slips mildly agree that this practice was effective at improving vegetation of slips. Farmers that didn't regrass slips believe it to be ineffective. Farmers believe that the economics of regrassing slips were marginal, especially compared with other expenditure items after storm events. Farmers that regrass slips appear to be motivated by non economic factors.

The most common farmer practise for regrassing slips was to helicopter on non-coated ryegrass/white clover seed, with no fertiliser onto slips more than 30 days after the event. Most farmers, whether they regrass or not, would do exactly the same thing after other slipping events.

From 1 ½ to 2 years after the storm event, on slip scars only 11% of farmers thought germination of natural seed was a success compared to 37% of farmers who had sown seed. On tailings, seed germination was considered a success by 53% of farmers irrespective of source of the seed. Only a quarter of farmers considered the persistence of germinated seed on slips a success, irrespective of its source,

The student measurements showed that slip scarps had regained 30% ground cover, the middle of the slip had 50% recovery and tailings had completely revegetated. Regrassing slips did not improve revegetation of tailings. But regrassed slip scars (scarp + middle) had 3% more clover, 7% more green grass leaf, 6% less dead matter, 8% greater eye assessed ground cover, and 11% more total cover by image analysis than non regrassed slips. Regrassing was more effective on shallow sloped slips. Regrassing improved ground cover by 20% on slips of less than 30 degrees, by only 10% on steep slopes

and not at all on very steep slopes. In the survey there was no benefit gained from regrassing mudstone soils. Other studies have shown natural revegetation of mudstone soils is faster than on sand stone based soils.

The overall impact measured, after 1 ½ to 2 years of regrassing of slips, was small and the effect of different practises became relatively minor compared to the slip variability. Research on regrassing slips after cyclone Bola showed an increased in pasture production especially when legumes were used. Regrassing research in Wairarapa showed that fencing and slow establishing seed improved pasture production of slips.

The survey results indicate that farmers need to keep resowing costs low if they wish to achieve a positive economic outcome from regrassing slips; given the limited advantages gained from current revegetation practises and the risk associated with poor germination and lack of persistence of the oversown seed.

Farmer survey on the regrassing of slips

Method

Federated Farmers have 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 slip damage on their farm were randomly selected from this database. These farmers were sent a questionnaire about the impacts of previous farm practise on slip incidence and subsequent slip prevention plans. They were asked to describe the remedial action they took for slip revegetation and their perception of the success or failure of their actions. They were also questioned on their perception of slip damage on farm saleability and capital value as well as the impact of previous farm practise on the occurrence of slip damage.

Questionnaires were collected from 81 farmers. Farmers were asked if they would be willing to have researchers visit their farms and to make additional measurements. Farmers were asked to identify 8 slips on their farm that represented the range of landforms and mass movement found in there. The slips was divided into three zones; scarp, mid slip and tailings.

One of the measured slips

A quadrat was placed on a representative area at each slip location. The percentage of the quadrat area covered by vegetation was estimated by eye and the percentage of vegetation type in terms of clover, grass and dead matter was also assessed, then trimmed to 2 cm above the ground and photographed. At each location a quadrat was also placed on a stable hill-side immediately adjacent to the sampling site and the same measurements were collected. The longitude and latitude for most of the slips were obtained with a GPS.

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 gives the total cover. The image analysis was over-ruled when green slime was inadvertently measured.

Photo for analysis taken on a slip scarp

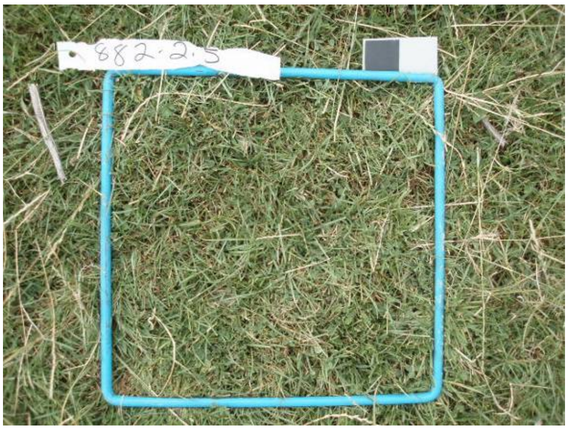


Photo from undisturbed ground

Farmer survey results were analyzed using general linear models procedures of SAS. The slip measurements are presented graphically as means with 95% confidence intervals calculated using survey means procedures of SAS.

Survey Results

Description of farm

Fifty one percent of the surveyed farms were located in the Manawatu, 21% in Wanganui, 19% in the Rangitikei, and 9% in the Tararua districts. The average topography of the farms was 15% flat, 33% rolling and 59% steep. Eighty percent of farms had more than 80% of the land area in pasture. Land use is described in (Figure 1).

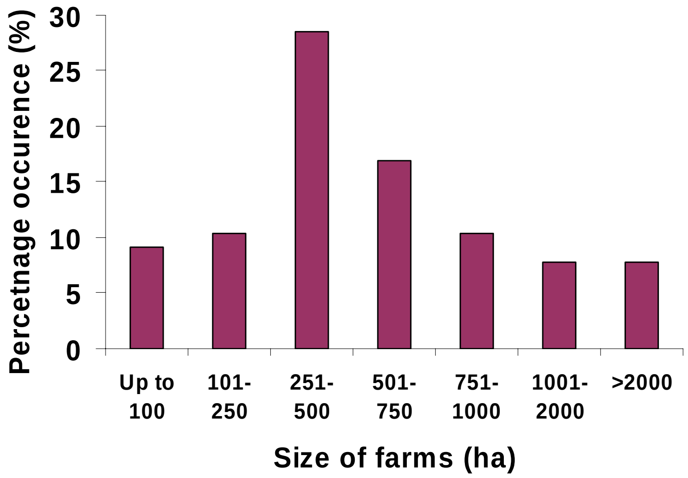


Figure 1: Distribution in size of farms surveyed

Seventy one percent of the farmers had breeding sheep on their farm and 39% finished lambs. Sixty three percent had breeding cattle on the farm and 35% finished cattle, 9% had deer and 11% cropped.

With respect to trees, 22% of farms had agro forestry, 52% had farm forestry and 70% had areas of bush. However each type of tree enterprise mostly occupied less than 10% of the farm areas (Figure 2).

Nearly all farms have densely treed areas but these occupy a low percentage of land area

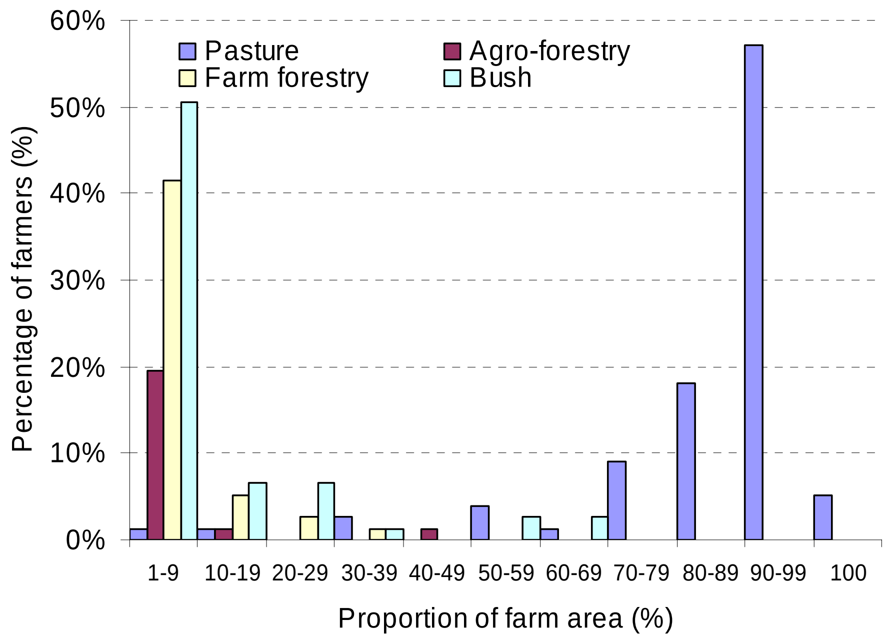


Figure 2: Proportion of farm area in pasture and various tree enterprises on the farm of respondents.

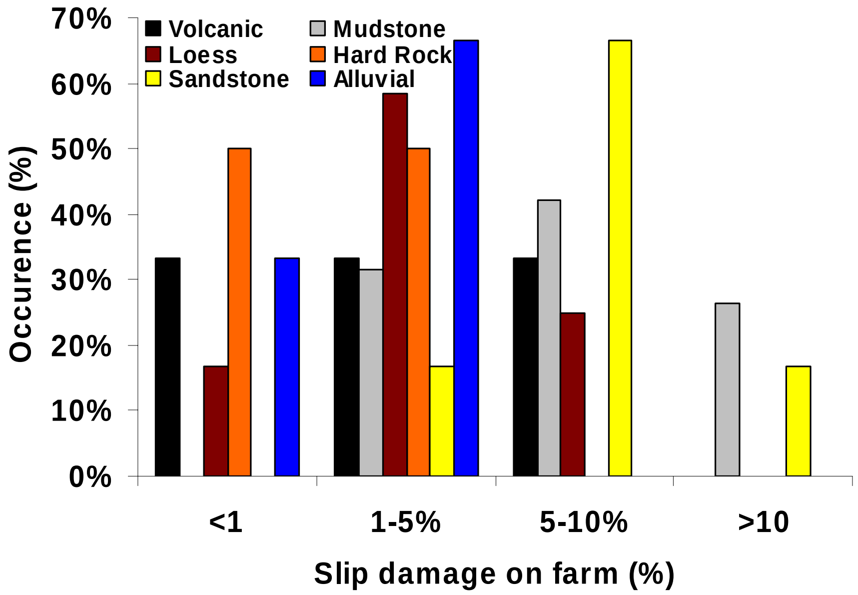
Slip damage

Seventy five percent of farmers assessed the area of the farm affected by slip damage at 1-10% (Table 1) More slipping was found on mudstone and sandstone soil types than on other soil types. (Figure 3).

The area of the farm affected by slip damage was relatively minor

Table 1: Farmers estimate of the area affected by slip damage.

	Percentage of farm area affected by slip damage				
	<1%	1-5%	5-10%	>10%	Other
% of farmers	8.5	35.2	40.8	11.3	4.2



Mudstone and sandstone soils were worse affected by slips

Figure 3: Farmers assessment of slip damage on their farm and primary soil type on the farm.

Slip pattern

Farmers were asked to described any association they saw in the slip damage on their farms with the geomorphology of the land or farming activities but a reasonable percentage.

(36%) of the farmers indicated that they could not see any patterns (Figure 4). However the next most commonly held opinion held by farmers was that slips are worse on steep slopes.

The pattern of slips was difficult to predict

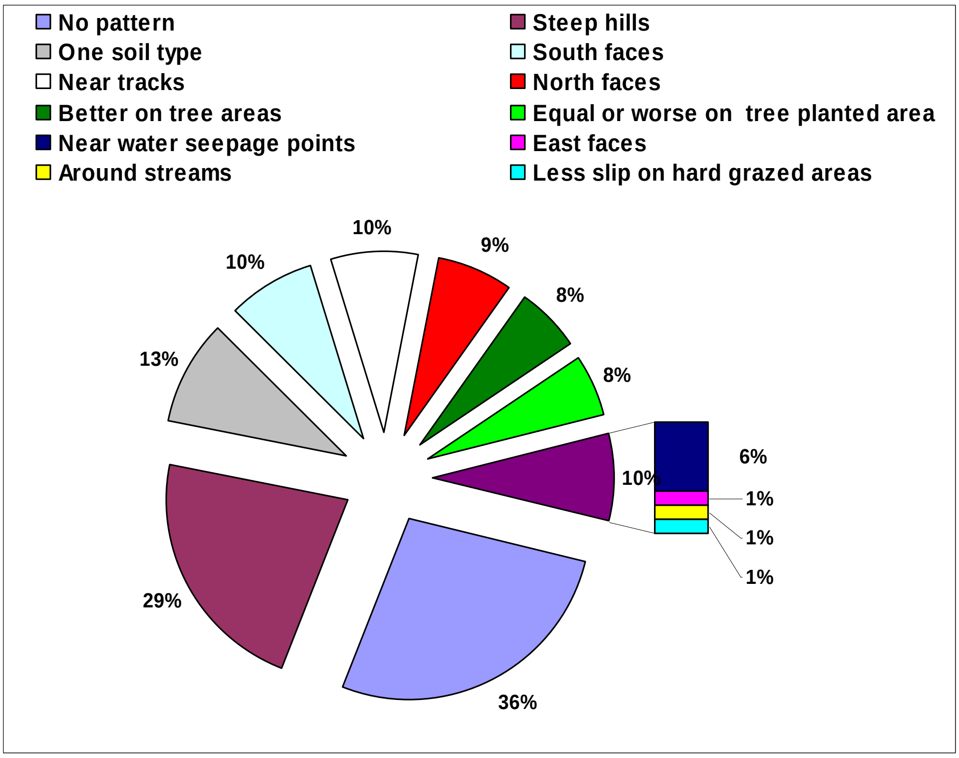


Figure 4: Farmers' opinion on what parts of the farm had worse slipping.

Impact of soil conservation

Effectiveness of tree planting

Farmers consider tree planting only partially effective at preventing slips during the storm event

Farmers were asked to rank the effectiveness of tree planning for the purpose of soil conservation from 1 ineffective to 5 highly effective in preventing slip damage.

According to the farmers planting trees was only partially effective (mean scores 2.5-3.0) at preventing slips (or erosion) in the face of this extreme storm event. The raw rankings do reveal that farmers are polarised on their assessment of effectiveness of trees (Table 2).

Grazed areas

Where farmers were still grazing under the trees, the farmer ranked space (2.6) versus dense (2.9) planting equally effective at reducing slipping on their farms. There was no difference in effectiveness between willows/poplars (2.8) and pines/gums/wattle (2.7). Research has shown that the effectiveness of a tree at holding a soil is related to the sum of its root biomass and root strength, which for an individual tree is highly related to the circumference of the tree trunk irrespective of species. The farmer survey showed that trees planted earlier (and therefore smaller) were less (P=0.09) effective than those planted later (2.5 vs 3.0). One research study concluded that well maintained, space poplars reduced soil erosion by about 60-70%, while poorly maintained poplar plantings had minimal effect. Possibly our plantings of poplars need to be better planned and maintained. Poplar poles planted at 50 per ha should be sufficient to reduce soil erosion over time to approximately 60% of densely treed areas once the stand reaches 10 years of age.

Retired areas

Farmers rated planting with trees and retiring the area from grazing as more ($P<0.07$) effective (3.4) at preventing slips during the storm event compared to continuing to graze the paddock (2.7). However retired areas were considered less effective at slip prevention if they had been retired for less (2.5) than two compared to more than two years (3.2). In areas that were retired from grazing, native bush (2.7) and pines and gums (3.2) were equally effective at preventing erosion. In areas retired from grazing, farmers perceived native scrub cover (2.3) to be less effective ($P<0.01$) than either regenerating large native trees (3.0) or farm forestry (3.3). The low score given for the effectiveness of 'dense planted retired areas' at preventing slips is surprising. It is generally accepted that closed canopy forest (bush, forestry or tall scrub) reduces soil erosion on unstable slopes by around 90% compared to pasture cover.

Farmers believe that dense planting of older trees in areas retired from grazing are the most effective at preventing slips

For all types of tree planting the farmers ranked plantations older than two years (3.1) as being more effective ($P<0.003$) than those that were younger (2.4). A few farmers commented that the area of the farm planted in forestry for erosion control actually slipped worse than other parts of the farm. These farms tended to be on mudstone soils though one was on the loess terrace soil.

Future tree planting

In grazed pasture, space plantings of willows/poplars were the most popular tree planting strategy for reducing slip damage before the storm and continued to be after the storm event and will be in the future (Table 4). Before the storm 34-46% of farmers had areas retired from grazing and planted with trees but only 3-9% of farmers intended to withdraw additional areas from grazing either since the storm or in the future.

Table 4: Percentage of farmers who had implemented particular tree planting strategies before the storm (farmers replying=70), since the storm and intend to in the future (farmers replying both = 49).

	Percentage of Farmers Replying (%)		
	Before storm	Since storm	In future
Planting allowing grazing			
Space planting			
Willows and poplars	70	49	39
Pines, gums and wattle	24	4	4
Dense planting			
Willows and poplars	16	5	7
Pine, gums and wattle	27	9	12
Planting trees along waterways/gullies	41	21	28
Areas retired from grazing			
Native Scrub cover	34	3	4
Regenerating large native trees	38	5	7
Farm forestry	46	7	9

Few farmers intend to remove further areas from grazing in the future

Table 2: Percentage of farmers who ranked the effectiveness (1=ineffective, 5 =totally effective) of plantation type for alleviating erosion.

	In Place Less Than Two Years						In Place More Than Two Years					
	No. farms	1	2	3	4	5	No. farms	1	2	3	4	5
Planting allowing grazing												
Space planting												
Willows and poplars	14	35.7	7.1	28.6	14.3	14.3	35	20.0	11.4	34.3	25.7	8.6
Pines, gums and wattle	5	60.0	0.0	20.0	0.0	20.0	12	25.0	8.3	25.0	25.0	16.7
Dense planting												
Willows and poplars	2	50.0	0.0	50.0	0.0	0.0	9	22.2	11.1	11.1	55.6	0.0
Pine, gums and wattle	4	50.0	0.0	25.0	0.0	25.0	15	13.3	6.7	20.0	26.7	33.3
Planting trees along waterways/gullies	7	71.4	0.0	0.0	14.3	14.3	22	31.8	18.2	18.2	22.7	9.1
Areas retired from grazing												
Native Scrub cover	5	40	20	20	0	20	18	27.8	27.8	16.7	16.7	11.1
Regenerating large native trees	4	50	25	0	0	25	23	13	13	22	30.4	21.7
Farm forestry	4	25	0	50	25	0	28	10.7	3.6	10.7	46.4	28.6

Table 3: Percentage of farmers who ranked the effectiveness (1=ineffective, 5 =totally effective) of a range of farm practices for alleviating erosion.

	Before storm							Future	
	No. Farms	Effectiveness in alleviating slip damage						No. Farms	No. New users
		Ave	1	2	3	4	5		
Surface, sub-surface drainage	29	3.0	10.3	17.2	41.4	20.7	10.3	14	4
Debris dams	14	3.3	14.3	14.3	14.3	42.9	14.3	7	2
Flues, chutes, diversion banks	9	2.4	33.3	22.2	22.2	11.1	11.1	9	7
Mechanical infilling or contouring	9	3.4	22.2	0	11.1	44.4	22.2	7	3
Different grazing management practises on slip prone areas (eg higher residual DM, increased fertiliser use, allow reseeding)	9	3.2	0	22.2	33.3	44.4	0	11	5

Other soil conservation practises

The effectiveness ranking of other soil conservation practises in minimising slip damage from highest to lowest was debris dams, mechanical infilling/contouring and drainage (Table 3). Flues /chutes and diversion banks were considered least effective and only 1 of the 8 existing users planned to build more of these in the future. Maximum usage was for surface and sub-surface drainage where 34% of farmers had these in place before the storm, but only 10-17% of farmers were using these other practises.

When Farmers (n=61) were asked to describe, 'what they will do in the future to prevent slips', planting trees was the most common reply (Table 5).

Table 5: The percentage of respondent (n=61) farmers intending to implement erosion control strategies.

Practise	**Descriptive**	
Plant trees	Vast majority of future tree planting will be poplars space planted or in gullies	48%
Have no plans		20%
Grazing management	Increase fertiliser and maintain higher residual	16%
Maintain waterways, drains, culverts	To move water more quickly and redirect it	13%
Retire land	Includes both paddocks, gullies and along water ways	10%
Earth works	Building of dams, contouring etc	8%
Change stock policy	Reduce size, number, winter grazing of cattle	8%
Change fences lines	To minimise damage	8%
Allow regeneration of scrub	and graze	5%
Done everything I can		4%
Regrass slips	1 year old slips	3%
Farm forestry		2%
Whole farm plan approach		2%

Space planting poplars is the most popular future practise for reducing slips

Farmers' opinion on the effectiveness of regrassing slips

In this survey 41% of farmers had regrassed slips and 59% had not and, not surprisingly, the farmers opinions were somewhat polarised. For example,, in response to a question about the effectiveness of regrassing, 38 of farmers disagreed with the statement and 43% agreed with statement while 19% sat on the fence (Table 6), resulting in a mean opinion that is close to neutral. However when separating the opinions of those that had, from those that had not regrassed their slips a clear picture was found.

Table 6: Percentage of farmers rating agreement with the statement "Regrassing slips at all times of the year is a waste of time because the sown plants don't persist"

Percentage of farmers				
Strongly disagree		Neutral		Strongly agree
1	2	3	4	5
12.2	25.7	18.9	23.0	20.3

Farmers were asked to score whether they had changed their opinions from before to after the storm event and very little change in opinion had occurred. The biggest rise (0.13 score units) occurred for the question that stated "Regrassing slips gave you something proactive to do in a disaster".

Biological effectiveness of regrassing slips

Farmers who hadn't regrassed believed that regrassing slips didn't work because seed doesn't establish or persist and were fairly neutral about whether it had any long-term benefit on revegetation of scars or slips (Figure 5). However farmers who had regrassed mildly agreed, but not strongly, that seed established, persisted and was of benefit in long-term vegetation. This is interesting because it appears that even the farmers regrassing slips are not strongly convinced as a group of its biological effectiveness.

For both groups of farmers there was a strong belief that regrassing slips improved revegetation of tailings and regrassing slips was ineffective if carried out in summer. This belief about regrassing tailings is contrary to research results which suggest that tailings regrass rapidly themselves without intervention.

Farmers who regrass slips mildly agree that it is effective at improving vegetation of slips. Farmers that don't regrass slips believe it is ineffective

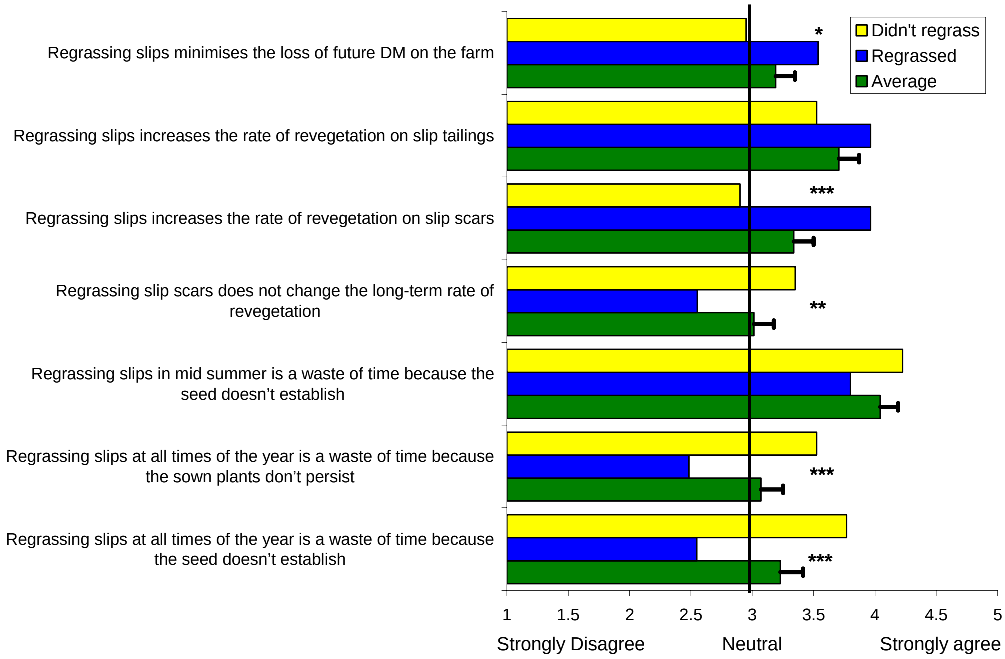


Figure 5: The perceptions of biological successfulness of regrassing slips. Bars are standard error. ***P<0.001, ** P<0.01, *<P<0.05 is statistical difference between farmers that did or didn't regrass slips.

Cost effectiveness of regrassing slips

All farmers believed that regrassing slips is of less priority than improving infrastructure and maintaining feed supplies. Farmers as a group were ambivalent about the economic benefits of regrassing. However farmers that hadn't regrassed strongly believed that regrassing slips was not cost effective while farmers who had regrassed mildly disagreed. This grouping also had disparate opinions on the impact of regrassing on future value of the farm (Figure 6).

Farmers believe that the economics of regrassing slips is marginal, especially compared with other expenditure items post storm events

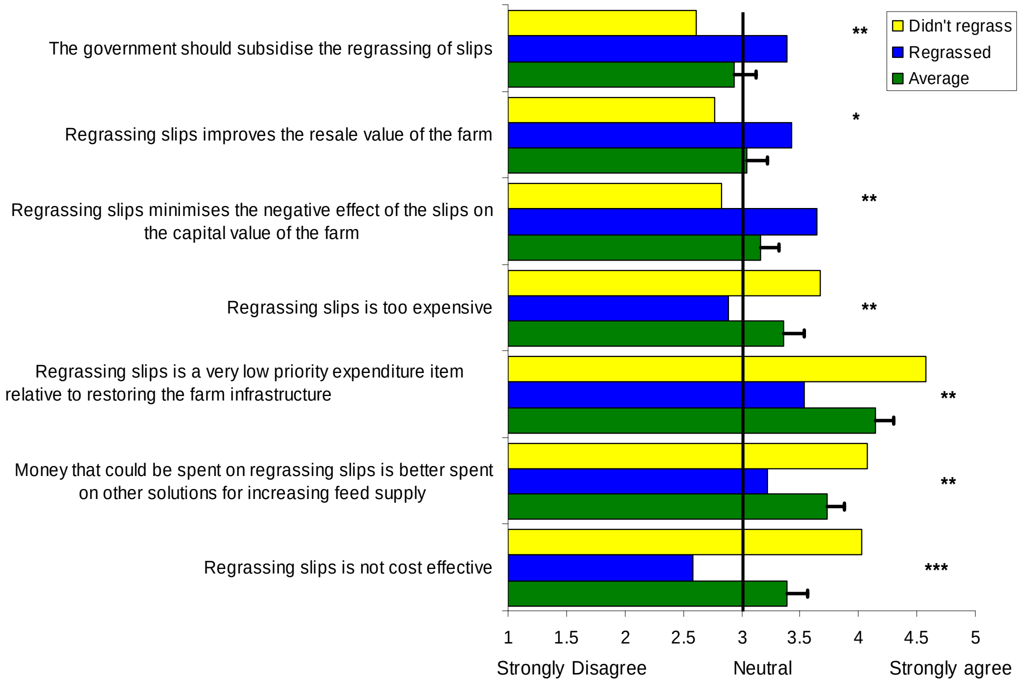


Figure 6: The perceptions of economic implications of regrassing slips. Bars are standard error. ***P<0.001, ** P<0.01, *<P<0.05 is statistical difference between farmers that did or didn't regrass slips.

Risk of failure, logistics and environmental aspects of regrassing slips

On average farmers believed that regrassing slips encourages topsoil formation and reduces runoff but doesn't reduce the chance of future slips. On average farmers believed that access to grass seed or contractors does not prevent the regrassing of slips. In general the farmers who did not regrass the slips perceived this practise as more risky than the farmers who did regrass.(Figure 7).

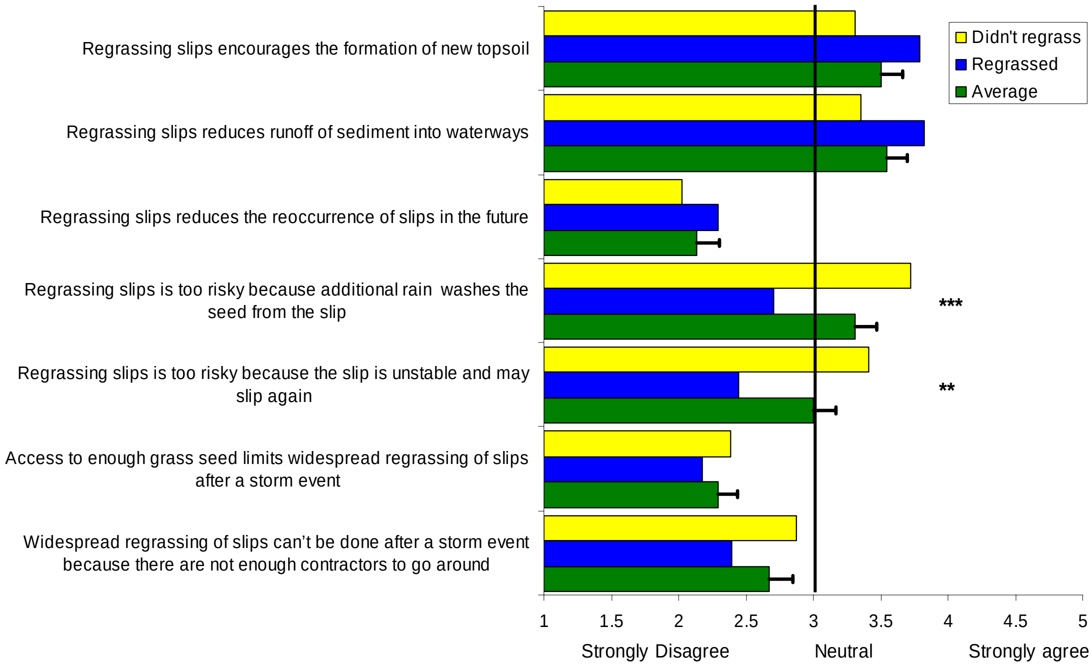
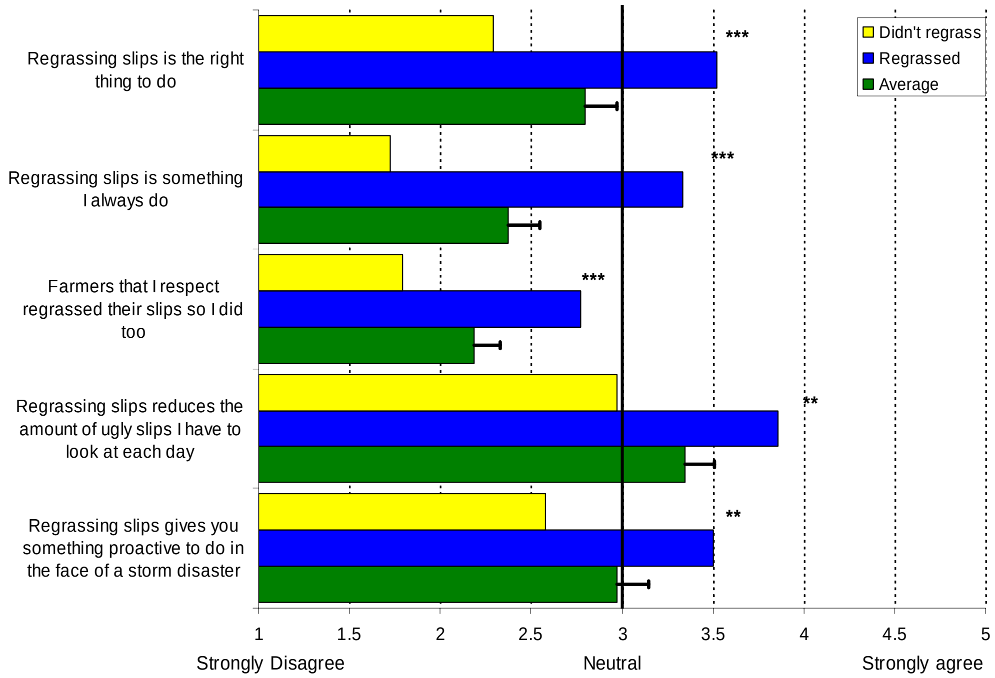


Figure 7: The perception of risk. Bars are standard errors. ***P<0.001, ** P<0.01, is statistical difference between farmers that did or didn't regrass slips.

Social aspects of regrassing slips

Farmers that had regrassed had a moderate belief that it was the right thing to do, should always be done and gave you something proactive to do (Figure 8). But farmers that hadn't regrassed strongly disagreed. It is in this section, rather than those above, where the greatest divergence of opinion occurred between those that did and didn't regrass slips is seen. Farmers who had regrassed were strongly motivated by not wanting to look at ugly scars each day while farmers that hadn't were neutral on this point. Both groups of farmers were not swayed by the actions of other respected farmers with respect to regrassing. This is unusual because normally uptake of technology by farmers is strongly influenced by other respected farmers. It appears that the decision to regrass slips by farmers is more of an individual "conscience" vote.



Do farmers consider regrassing slips the right thing to do?

Figure 8: The perceptions of farmers in relation to the social aspects of regrassing slips. Bars are standard error. ***P<0.001, ** P<0.01, is statistical difference between farmers that did or didn't regrass slips.

Farmers ranking of the effectiveness of slip revegetation

Farmers were asked to assess the effectiveness of revegetation on the scarp and tailings of the slips with respect to germination and persistence of sown or natural seed stocks after the 2004 storm event. This data has been analysed to present the likelihood of success or failure to give an indication of the riskiness of the procedure.

Between 52-58 farmers provided data on natural revegetation and 23-28 on sown seed, with only 17-19 farmers distinguishing between sown clover or grass seed. Some farmers ticked the "didn't know" box for some of this section and the small sample size has limited the data analysis.

On slip scars only 11% of farmers thought establishment of natural seed was a success compared to 37% of farmers for sown seed. On tailings, seed germination was considered a success by 53% of farmers

Initial seed establishment

Slip scar

When scarps were left to naturally vegetate, only 11% of farmers thought initial establishment was successful (score 4 or 5) and 63% considered it a failure (below 3). Following regrassing of slip scars 36%-38% of farmers considered it a success and 38-39% considered it a failure (Figure 9).

Slip tailing

Establishment was more successful on tailings where, for all seed sources, 50-56% of farmers ranked establishment as a success and only 13-15% thought establishment failed (Figure 9).

Persistence

Slip scar

__Only a quarter of farmers considered the persistence of germinated seed on slips, irrespective of its source, a success__

On the slip scars between 43 and 47% of farmers considered the persistence of either sown or natural seeded plants respectively to be a failure and only 22-26% of farmers considered the persistence to be a success. On slip scars one third of farmers considered the persistence of sown clover a failure and an equivalent considered it a success (Figure 9).

Slip tailings

On slip tailings only 8% of farmers considered the persistence of natural reseeding a failure compared to 21% and 24% for sown grass seed and clover respectively. Natural reseeding persistence was consider a success by 45% of farmers compared to 43% and 36% for sown grass seed and sown clover seed. (Figure 9).

Revegetation

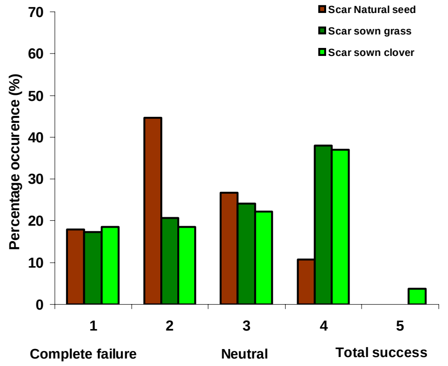
One and half years after the February 2004 storm, 54% of farmers ranked revegetation of slip scars as a failure and only 10% considered revegetation was successful. The reverse relationship was found on tailings where only 9% considered revegetation a failure and 62% considered it successful (Figure 9).

The average success score for revegetation 1.5 years later was higher ($P<0.001$) on tailings (3.8) than for slip scars (2.8). The success score for revegetation after 1.5 years tended to be higher on regrassed scars than those left to natural vegetation (2.7 vs 2.4 $P=0.11$) but there was no difference on the tailings (both 3.8). According to the farmers' perception soil type, slope or aspect were not implicated in the success or failure of revegetation.

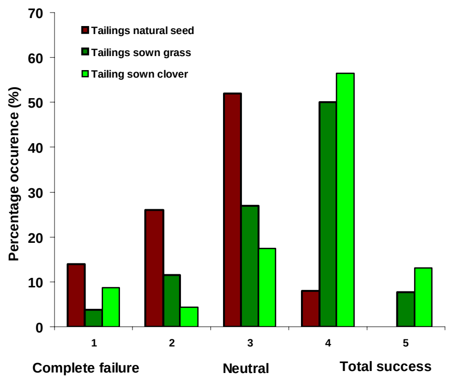
Farmers perception of success or failure of regrassing slips from natural or sown seed.

Initial establishment

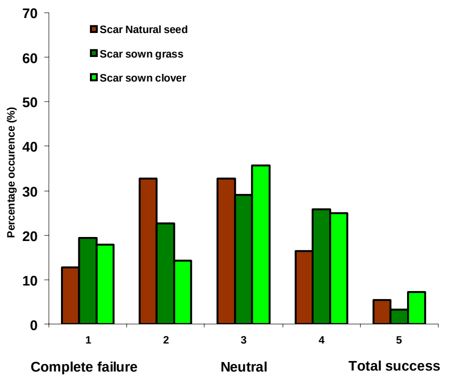
SLIP SCARS

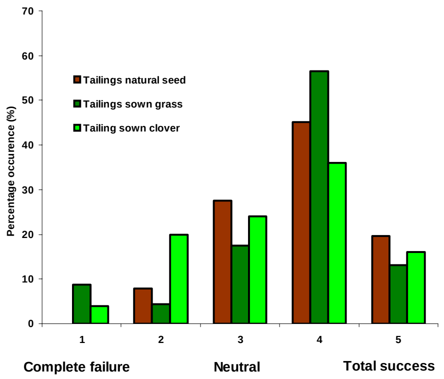


SLIP TAILINGS



Long term persistence





Revegetation after 1.5 years

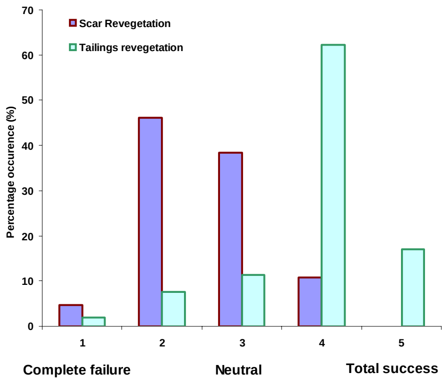


Figure 9: Distribution of the ranks given by farmers of natural or sown seed establishment, long term persistence and overall revegetation after 1.5 years on slip scars or tailings.

Slip regrassing practises by farmers

Of the 35 farmers reseeding slips, 61% put the seed on using a helicopter, a surprising 32% by hand, 5% by plane and 3% using a vehicle pulled spinner. Sixty two percent of farmers didn't put on fertiliser with the seed, 29% put phosphate based fertiliser and 6% put on phosphate + nitrogen and 3% put on lime. Most farms reverted subsequently to normal farm fertiliser programmes, slips included.

The most common farmer practise for regrassing slips was use a helicopter to fly bare ryegrass/white clover seed without fertiliser onto slips more than 30 days after the event

Sixty five percent of the farmers used bare seed and the remainder used coated seed and none used slug bait. It is recommended best practise that coated seed be used. Of the 29 respondents, 79% sowed clover and ryegrass, 14% clover only, 10% bush burn and 3% grass alone. Seed was applied by 48% of farmers more than 30 days after the storm, 27% within 10-29 days and 24% less than 10 days.

The weather conditions following the 2004 storm event where warm and moist and this is reflected by 87% of farmers stating that post sowing weather conditions were good for germination. A few properties experienced snow and the slips reopened and/or new grass was pulled from the slips by the snow. Three farms reported that dry faces hadn't fared well. A few others reported wet and cold conditions didn't help and may have washed seed from slip. Another said birds eat much of the grass seed.

Farmers had limited capacity to protect regrassed slips because fences had been lost and fencing off slips is normally considered cost prohibitive. As a consequence 73% of farmers maintained normal grazing management or set stocked the paddocks. Of the remaining farmers, 15% reduced grazing pressure on the paddocks, 4% only grazed the paddock with sheep and 8% fenced off the slips.

Most farmers that regrassed slips would do it again

When asked what farmers would do differently after storm damage in the future there was a wide range of response. Eighty percent of those who didn't regrass slips last time said they would do the same next time. Whereas of the farmers who regrassed slips, 45% would do exactly the same in the future. However of the 29 respondents who regrassed slips, only 4 wouldn't regrass slips again, 2 would put on only legume, 3 would put seed on earlier, 1 wouldn't regrass tailings and 3 would take more care with timing with respect to rain.

Half the farmers indicated that targeting good weather conditions for sowing and then hoping for good weather conditions after sowing was the most important key success factor in regrassing. A further 18% of respondents said that getting the seed on quickly before the slip had dried was very important. Other factors such as using legume seed or fencing off the slips were thought to be minor contributing factors to the success of revegetating the slips. Thirteen percent of farmers said regrassing was never successful.

When considering the success of revegetation of slips farmers gave the highest ranking when oversowing occurred 5-9 days after the event (3.4) or 10-29 days (3.0) whereas those that got the seed on the slip more than 30 days after the event (2.5) and within 5 days of the event (1.7) had lower ($P<0.02$) had lower success rates of revegetating scarps. However, the data is not well balanced with respect to number of slips per group and other environmental factors such as soil type, region etc, and this effect of timing is not apparent in the measurements of the slips conducted by the students.

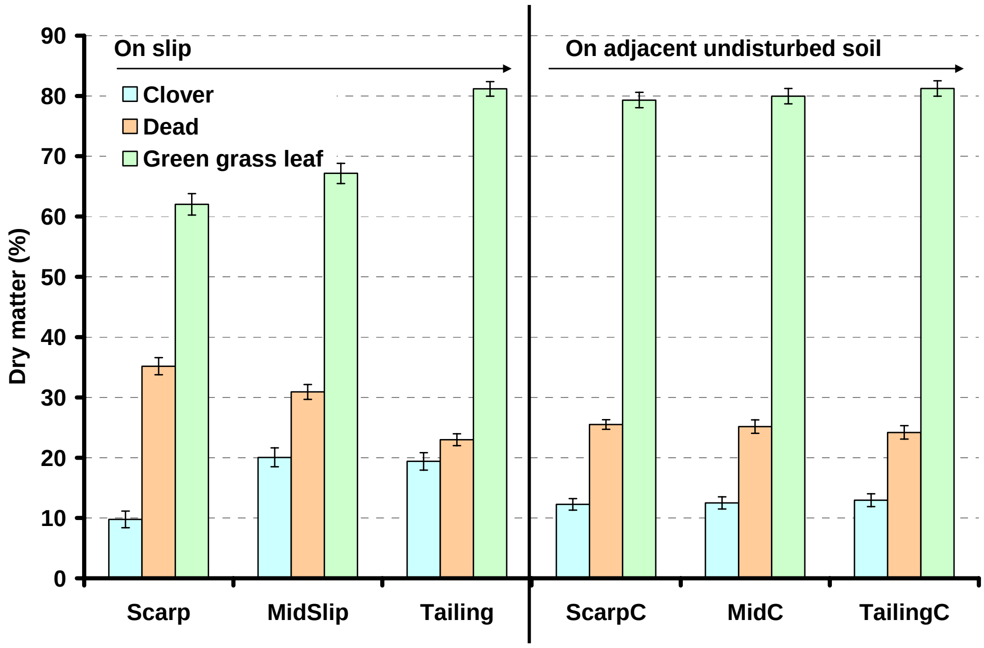
There were no effects of grazing management, fertiliser use, seed used, method of seed administration on farmer assessments on success of revegetation of scars or tailings. However farmers consistently indicated that good growing conditions after the sowing was important.

Student measurements on slips

The slip face is composed of a scarp at the top which is usually very steep and is composed of subsoil or parent rock type (low fertility). Below is the loose, shallow sub soil that makes up most of the slip face (middle of slip). Slip scarps and sometimes the slip middle have low moisture holding capacity, low organic matter and very low nitrogen status.
Slip debris tailings (or run-out) is the zone where the majority of the slip accumulates as a tumbled mixture of deeper soil and buried vegetation (tailings).

Slips vs undisturbed ground

Composition: One and half years after the storm event the slip middle and tailings have 6-7% more clover than undisturbed ground. Slip scarps have 2.6% less clover than undisturbed ground and 9% more dead matter. On the middle of the slip and on the tailings the dead matter percent is similar to undisturbed ground (Figure 10)



Proportionately the slip middle and tailings grow more clover

Figure 10: Eye estimates of vegetation composition. Bars are 95% confidence intervals, where bars do not overlapped differences are statistically significant.

Clover growth on a slip

Ground cover: The average eye assessed ground cover by the students was 22, 38 and 85% on slip scarp, middle and tailings compared to 93% on undisturbed ground. The same patterns were seen in the image analysed green and total cover though the image analysis gave higher values for total cover (Figure 10).

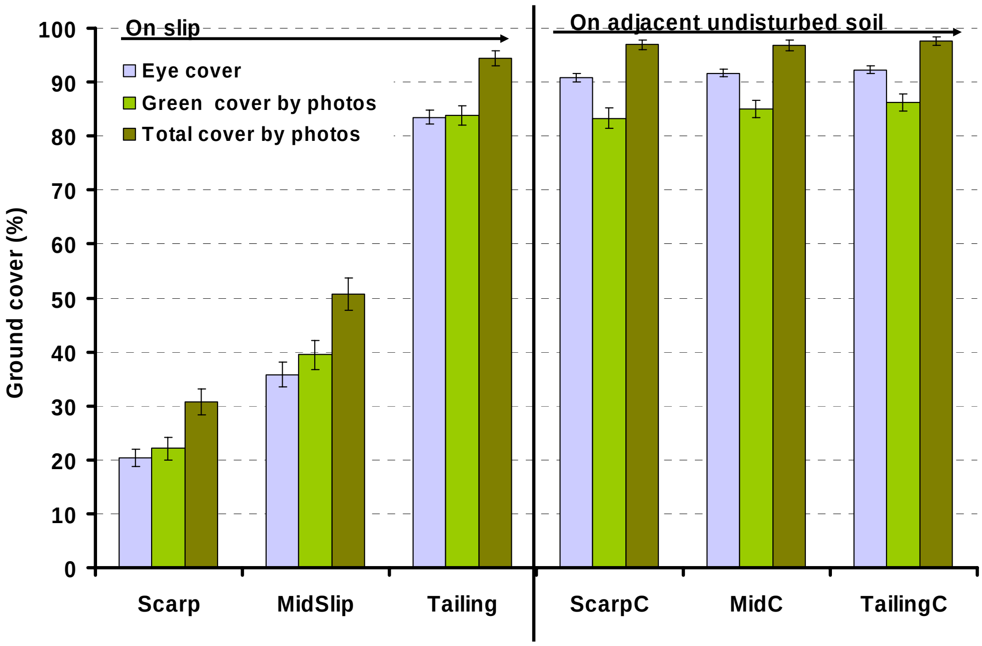


Figure 11: Comparison of eye assessed ground cover (% area with vegetation), image analysed green and total cover for scarp, middle and tailing of slips and adjacent undisturbed ground. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

The results from this study support other research which showed that tailing debris revegetates quickly, within 6 to 12 months, due to plant tillering through the topsoil, and from dormant seeds already present in the upper soil layer. Research has shown that in some instances subsequent regrowth on these tailings is higher (up to 30%) than equivalent non-eroded slopes. But immediately after the event the base of these slips often poses the greatest risk to stock losses from bogging or entrapment.

The face (scarp+middle of slip) composes around 20 to 40% of the total slip area. Analysis post-Bola showed that this face:tailing ratio was largely independent of slip slope and storm rainfall. The face:tailing ratio was consistent regardless of parent material. Face percentage relative to entire area of the slip for mud and siltstones range between 20 and 25%, volcanic ashes 30%, sandy siltstones 35 and sandstones 40%. The loss of production resulting from a slip is much less than first appears because productivity on the tailings offset the loss of grazing from the face.

Research on natural revegetation of slips shows that the slip face progressively become colonised by pasture species. However the loss in production continues because of the presence of bare soil, impaired water holding capacity and low fertility levels.

The student's eye assessment of the ground cover on the slip face after 1½ to 2 years was 27%. This is slightly higher than the estimate for pasture production found from research at equivalent time period (Figure 12). This is expected because on a slip both reduced ground cover and rate of growth will contribute to the lost of pasture production.
Research shows it takes 20 years or more for substantial recovery and, in some soils, full recovery never occurs because soil depth remains less than that of non-eroded sites.

After 1½ years slip scarps only have 30% ground cover, the middle of the slip have 50% ground cover but tailings have completely revegetated

Research show that if the slip has removed most of the soil i.e. down to mudstone or sandstone parent rock) pasture recovery will be retarded as shown on the Taranaki (sandstone) (Figure 12). Rock weathering will be required to reform the soil before appreciable pasture establishment can occur. Other slips may still retain a depth of soil though it will be substantially reduced.

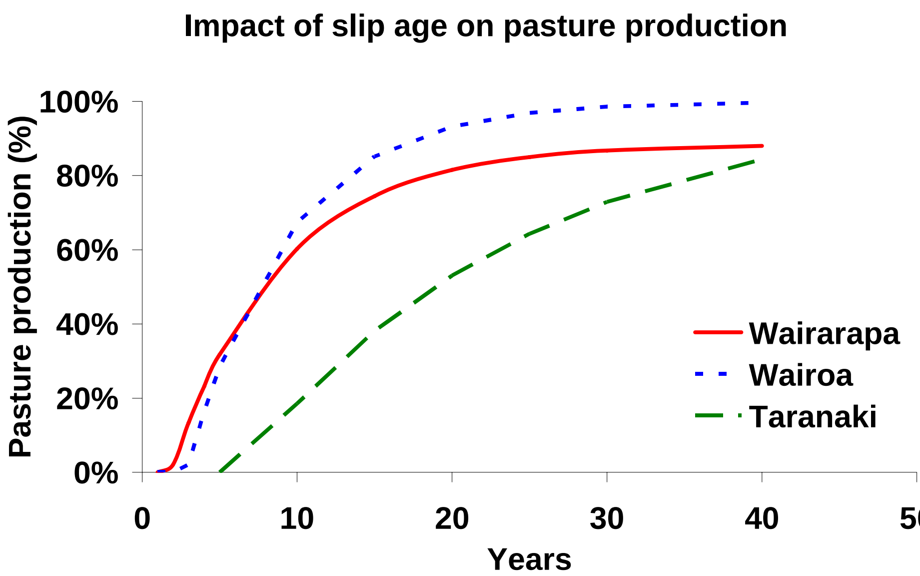


Figure 12: Pasture production following natural revegetation of slips in three different regions.

Impact of regrassing

Overall

Tailings: There was a 4% advantage to regrassing tailings in clover content but no other differences were found (Figure 13).

Regrassing slips had minimal impact on tailings

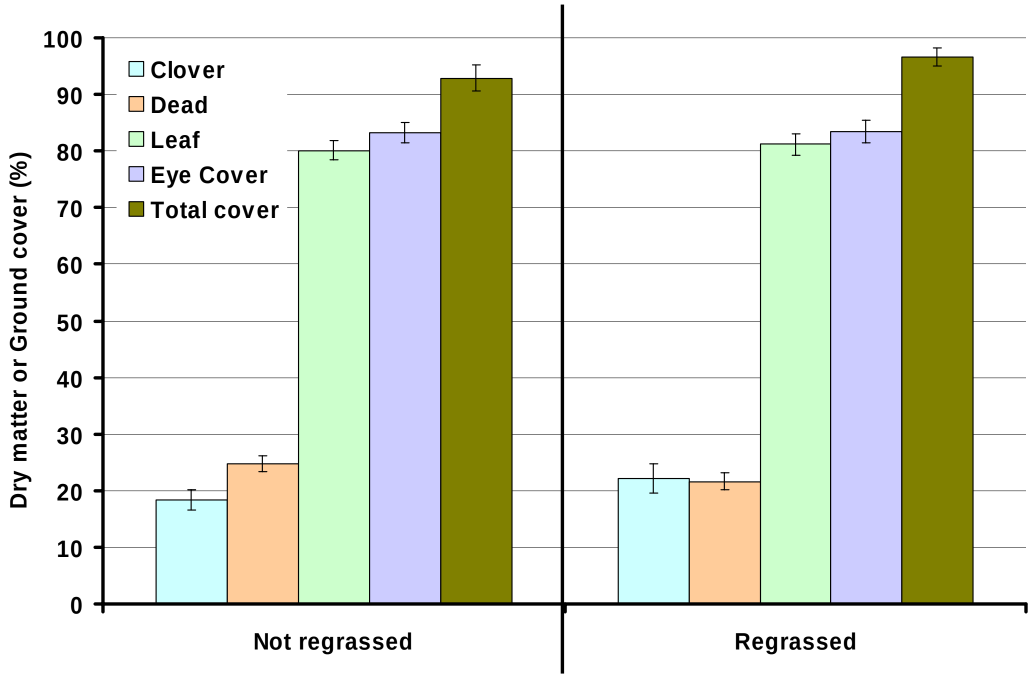
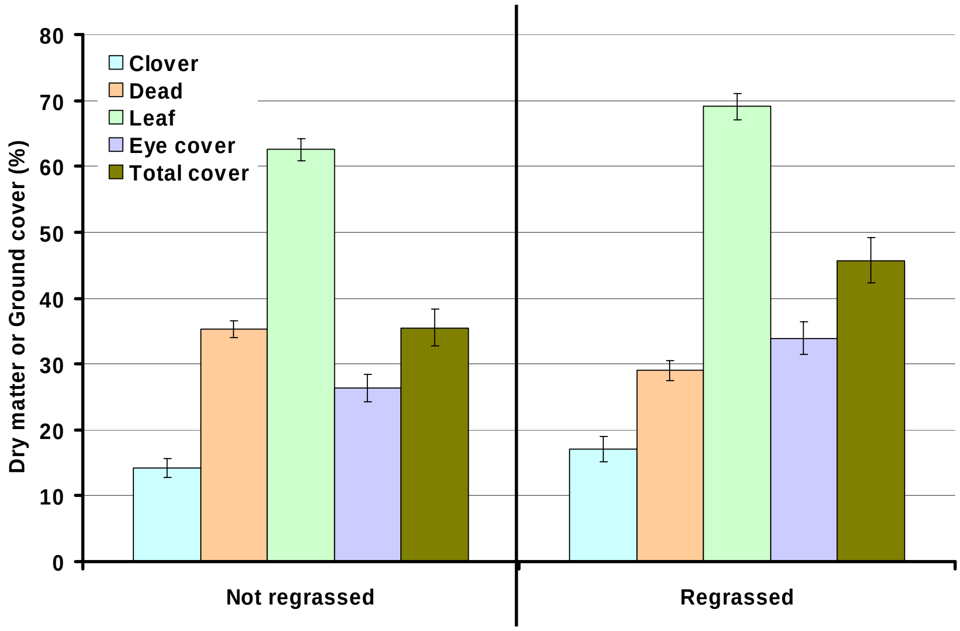


Figure 13: Comparison of clover as a percentage of green mass, dead as a percentage of total mass, and ratio of green grass leaf relative to total grass present and eye assessed ground cover (% area with vegetation), image analysed ground cover for regrassed tailings. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant

Slip: The effect of regrassing was similar on both the scarp and middle of the slip, so the data was combined.

After 1.5 years, regrassed slips have 3% more clover, 7% more green grass leaf, 6% less dead matter, 8% greater eye assessed ground cover, and 11% more total cover by image analysis than non regrassed slips (Figure 14). This effect of regrassing is substantially smaller than the 30-50% improvement in pasture production achieved 2-5 years after oversowing slips, in research studies, in Gisborne and Wairarapa. However, the survey data includes farmer data when regrassing failed.



Regrassing slip faces gave small improvements in botanical composition and ground cover

Figure 14: Comparison of clover as a percentage of green mass, dead as a percentage of total mass, and ratio of green grass leaf relative to total grass present and eye assessed ground cover (% area with vegetation), image analysed total cover for regrassed slips (scarp+middle). Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

Regrassed slip face

Slope

The slope categories are; moderate for less than 30 degrees, steep for 30-40, and very steep for more than 40 degrees.

Slip on twenty five degree slope

Slip on forty eight degree slope

Botanical composition: Clover content was higher in the more adverse conditions on very steep slopes compared to moderate slopes. There was 9% more clover found on the moderate slopes of the regrassed slips compared to the non-regrassed slips. The was less dead content on the regrassed slips on both moderate and steep slopes compared to the slips that weren't regrassed but there was no difference between them on very steep slopes (Figure 15).

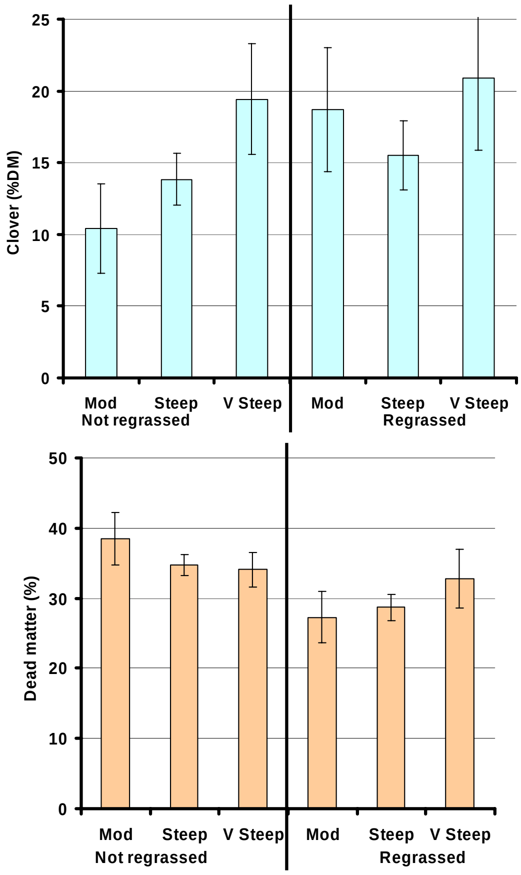
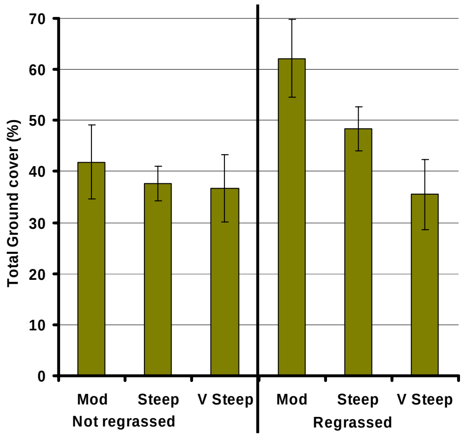


Figure 15: Clover as a percentage of green mass, dead as a percentage of total mass on different slopes on slips (scarp+middle). Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

Ground cover: Regrassed slips had 20% more ground cover on slopes less than 30 degrees, and only 10% more on steep slopes compared to slips that were not regressed. There was no difference in the amount of ground cover between the regressed and non-grassed slip on the very steep slopes (Figure 16).

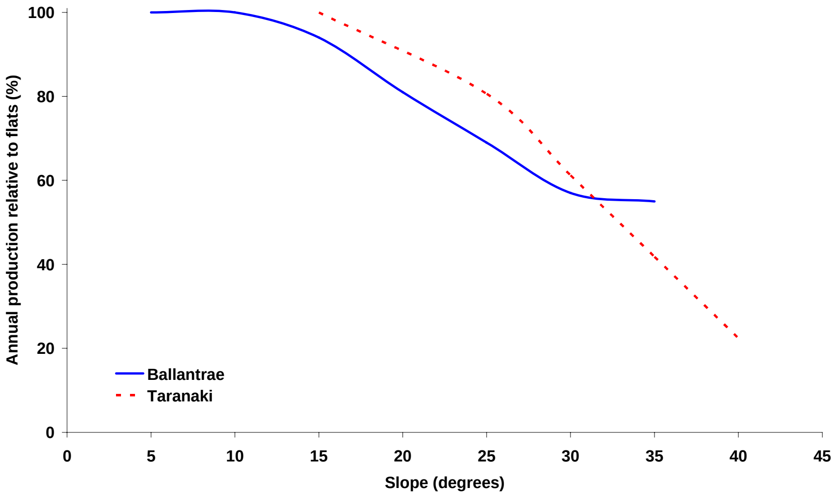


__Regrassing was more effective on less steep slips__

Figure 16: Effect of regrassing on total ground cover assessed by image analysis on different slopes on slips (scarp+middle). Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

Slips occur predominantly on the steeper (over 28 degrees) slopes and therefore less productive areas where feed utilisation efficiency and feed quality is poorer compared to flats or rolling country. This needs to be recognised when assessing the impacts of slips on overall farm pasture production and decisions around where to the regrass or plant trees.

At the Ballantrae research station (summer wet hill country, well fertilised flats producing 15 000 kg DM/ha, steep hills producing 8000 kgDM/ha) researchers found a reduction in pasture production as slope increased regardless of soil fertility but that this effect diminished at very high slope angles (see Figure below). On Taranaki hill country with pasture on sandstone derived soils (14 000 kgDM/ha on flats and 6800 kg DM/ha on very steep hills) a similar relationship existed. More reliance should be given to the Ballantrae data because it is derived from an experiment specifically designed to look at the effect of slope on pasture production.



__Pasture production decreases as slope increases__

Figure 17: Relationships between pasture production and slope angle.

Soil type

Soil types were classified according to their origin i.e. volcanic, mudstone (papa; 104 slips), loess terraces (Makuri, Whetukura, Kupoa, Kiwitea, Dannevirke, Kiwitea, Halcombe, Taihape, Kairanga silt loams; 78 slips) and because of low numbers the rest of the volcanic and sedimentary soils were grouped (53 slips) with the final category unknown (162 slips) because information hadn't been provided by the farmer.

Soil type had no effect on regrassing of tailings.

Botanical composition: On slips, clover content due to regrassing was unaffected by soil type with the possible exception of Loess soils . Dead matter content was reduced by regrassing in all but mudstone soil types (Figure 18).

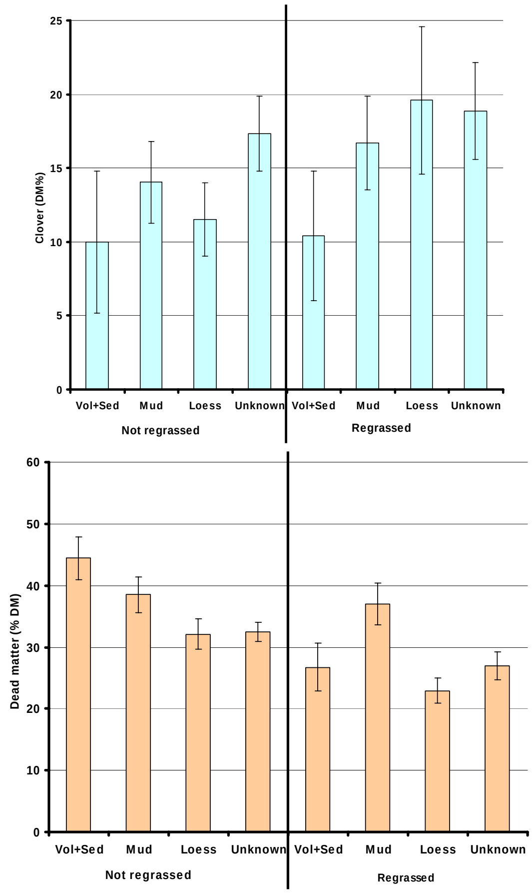
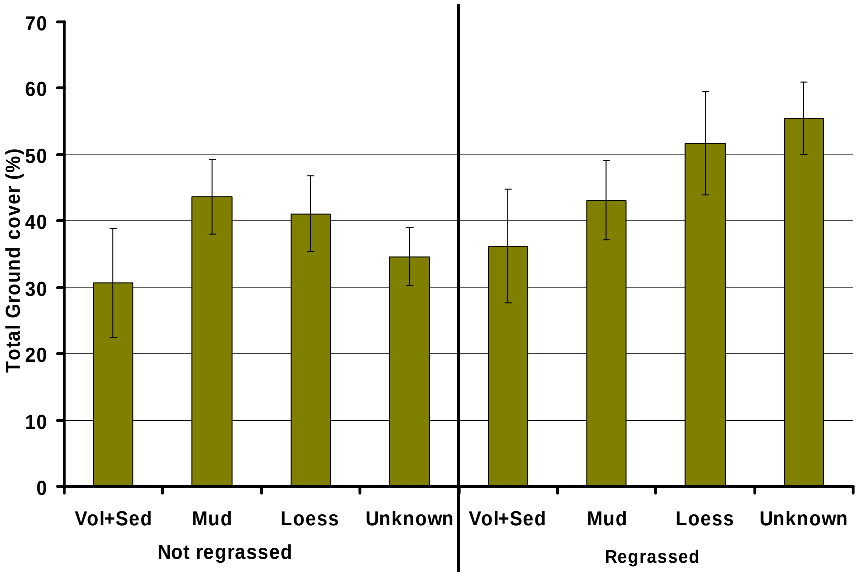


Figure 18: Effect of soil type on clover content and the amount of dead material in the ground cover on the scarp and middle zones of slips. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

Ground cover: Ground cover was unaffected by regrassing on mudstone, vol+sed and improved by 10% on loess soils and by 20% on unknown soil types (Figure 19). Research has shown that pasture recovery on slips on mudstone soils is better than those on sandstone materials because of the finer material and ability to retain moisture for longer periods. The results from this survey don't support previous research but this is confounded by the combined categories and the large number of slips of which the soil type was unknown.



In the survey there was no benefit to regrassing mudstone soils

Figure 19: Total ground cover as assessed by image analysis on slip faces (scarp+middle) on different soil types (scarp+middle). Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant

Regrassing Methods

The effects of regrassing methodology with respect to type of seed, application method, timing of sowing, fertiliser application were difficult to analyse because the numbers of slips in various combination were small and unbalanced (Figure 20, 21, 22).

The overall impact of regrassing of slips was small and the effect of different methodologies was minor relative to the variability in the responses in cover and measurement variability. In addition, most of the farmers put on a ryegrass+clover mixture with no fertiliser more than 30 days after the storm event which resulted in very small numbers of slips representing other methodologies. The farmer results encompass both the effectiveness of the methodology (like research results) but also the variability between farms associated with success of failure of seed establishment.

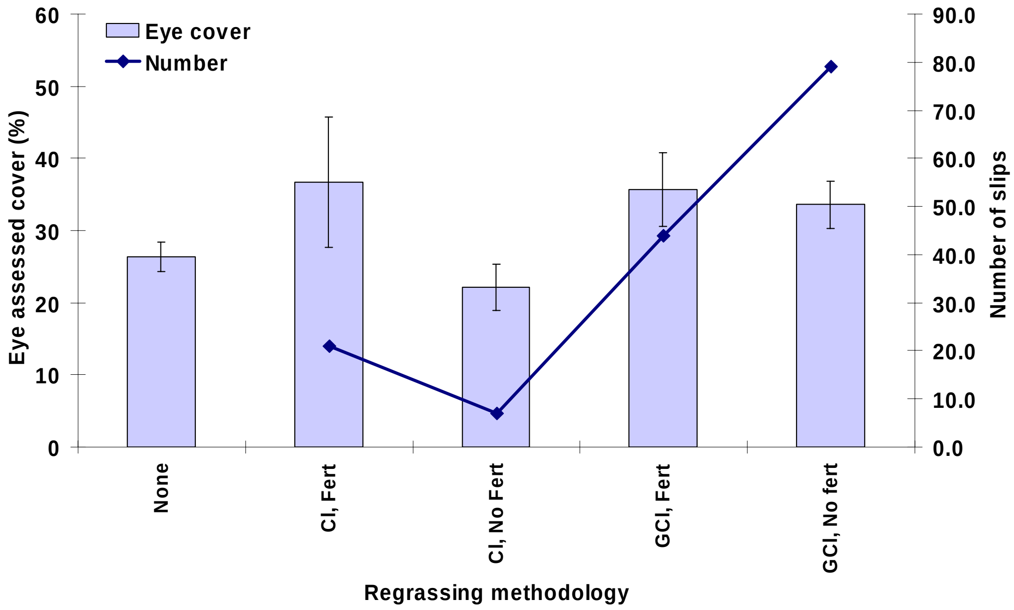


Figure 20: Effect of regrassing methods on eye assessed ground cover on slips that were not regrassed (none) and regrassed slip faces (scarp+middle) following application of different seeding mixtures (Cl=Clover seed only, GCl=Grass and clover mix) and fertiliser (Fert=fertiliser applied with seed, Nofert=no fertiliser with seed) and number of slips sampled in each group. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

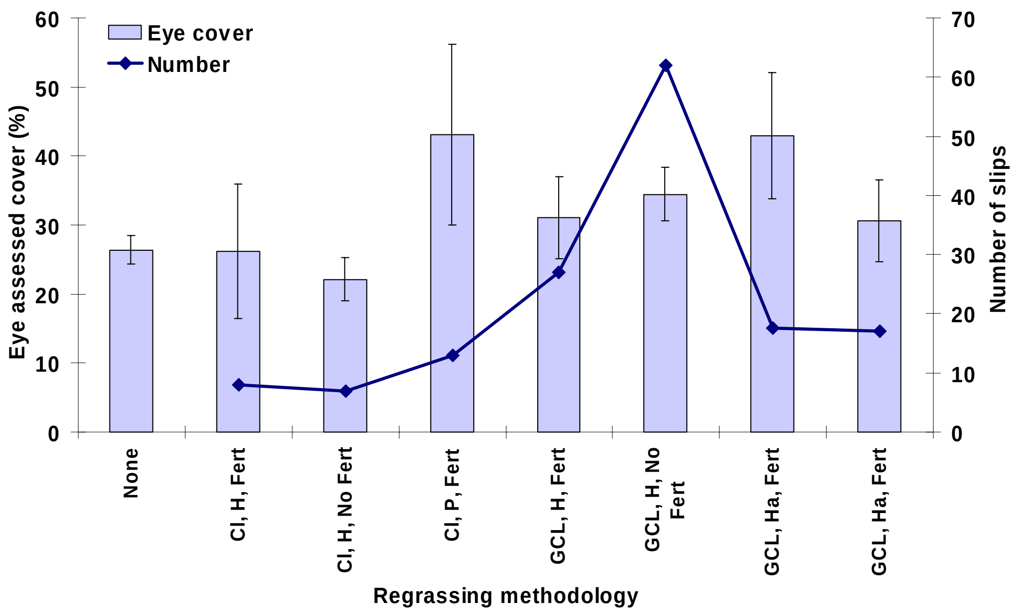


Figure 21: Effect of regrassing methods on eye assessed ground cover on non regrassed slips (None) and regrassed slip faces (scarp+middle) following application of different seeding mixtures (Cl=Clover only, GCl=Grass and clover mix) using different methods of application (H=helicopter, P=plane, Ha= by hand) and fertiliser (Fert=fertiliser applied with seed, Nofert=no fertiliser with seed) and number of slips sampled in each group. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

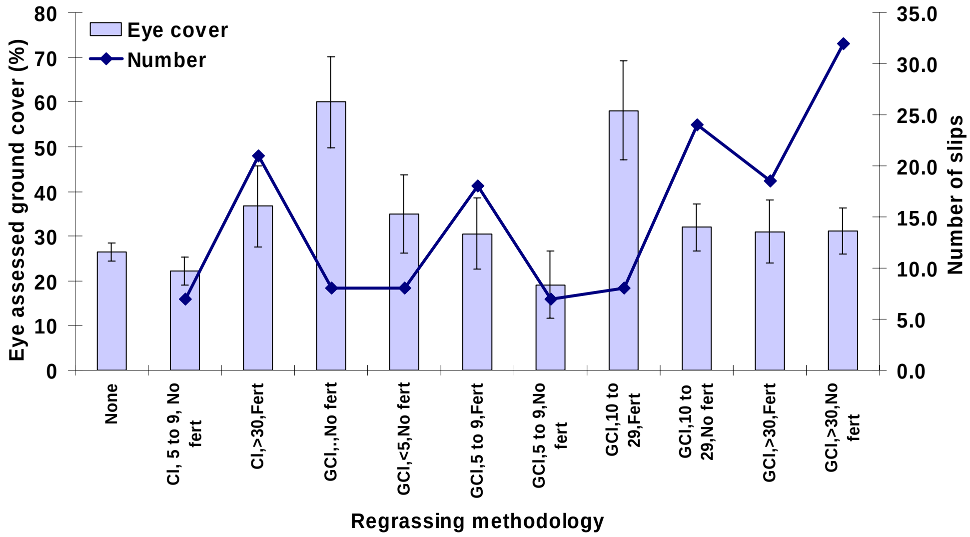


Figure 22: Effect of regrassing methods on eye assessed ground cover on non regrassed slips (None) and regrassed slip faces (scarp+middle) following application of different seeding mixtures (None=not regrassed; Cl=Clover only, GCl=Grass and clover mix) at different time intervals (<5= less than 5 days after storm event, 5 to 9 days, 10 to 29 days, more than 30 days) and fertiliser (Fert=fertiliser applied with seed, Nofert=no fertiliser with seed) and number of slips sampled in each group. Bars are 95% confidence intervals, where bars do not overlap differences are statistically significant.

In Gisborne, post Cyclone Bola research was conducted on slips of moderate to steep slopes (20-50 degrees), of low fertility (pH 6.3, Olsen P 6, K 7 and sulphate 3) and shallow (5-8 cm of deep exposed subsoil overlaying mudstone). These unfenced slips, with only maintenance levels of fertiliser, were oversown (had to be done twice because first sowing failed) with a variety of treatments. Grasses either as monocultures or in the standard ryegrass mixtures had little effect on revegetation of slips in low fertility hill country. Maku lotus and red clover were the most successful legumes oversown for fast slip coverage (Figure 23).

Research on regrassing slips after Bola increased pasture production especially when legumes were used

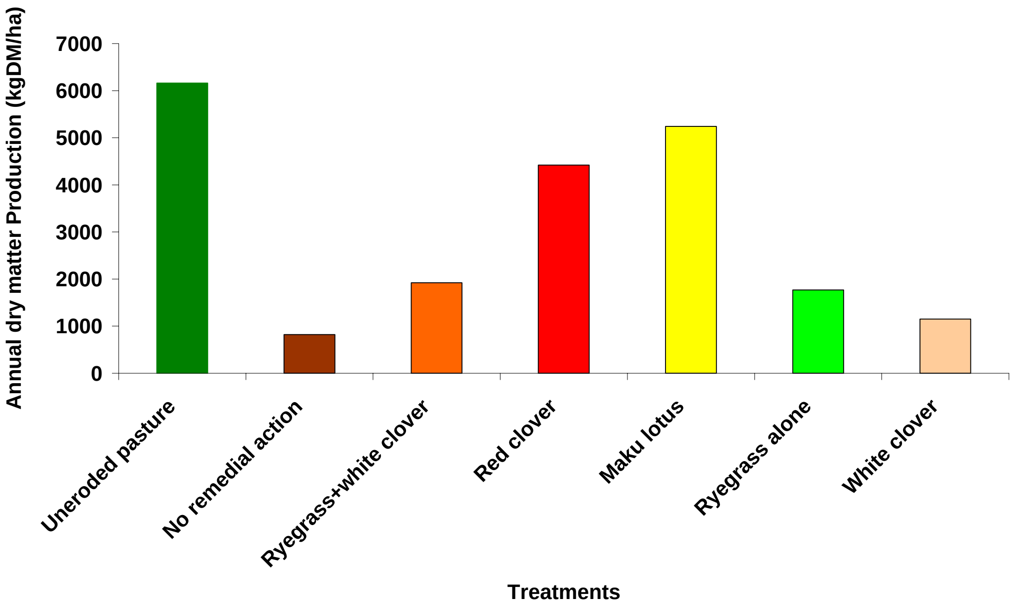


Figure 23 : Pasture production two years after over sowing with various seed mixtures after Bola in a summer dry area.

In another trial site in Wairarapa (average rainfall 1075 mm, Masterton) was located on fossilerfous siltstone soils with thin soils (0-34 cm) and Olsen P of <6 and pH 6.4 with slips equally distributed on both North and South aspects. On recent slip scars 3 seeding treatments and 3 fertiliser treatments were applied in May with and without fencing.

Fertiliser treatments were no fertiliser, 250 kg/ha S-superphosphate annually, and S-superphosphate plus 100 kg N/ha annually. Seeding treatments were; no seed, a slow-establishing mixture (7 grasses including cocksfoot and browntop, plus 6 legumes and yarrow), and a fast-establishing mixture (ryegrass, Yorkshire fog, prairie grass plus 3 legumes and chicory). Half the scars *were fenced* to exclude grazing livestock for $2^1/_2$ years.

After the first $2^1/_2$ years, in Wairarapa, the area of bare ground decreased more rapidly on the fenced than the unfenced areas, and this was hastened by seed application and fertiliser N increased the amount of plant material/litter on the slips. Over this time white clover and lotus (on fenced slips only) were the most effective legumes. Ryegrass and browntop were the major grasses but content was little affected by fertiliser and seed treatments. On the fast-establishing seeded slips, Yorkshire fog (8%) and cocksfoot (6%) were the most prominent of the other grasses.

Pasture production in years 3 to 5 was 80% greater on fenced than unfenced sites (5220 vs. 2890 kg DM/ha/yr). Production was not influenced by fertiliser treatment or fast-establishing seed application; and slow-establishing seed application increased production 40% (Figure 25). Unfortunately fencing of slips is usually cost prohibitive on farms.

Relative to the research trials the benefits of regrassing found on farmers properties were much lower than recorded on research trials. This is probably because the relative short time interval between storm event and survey time. But the farmer data also encompasses the riskiness of regrassing slips associated with failed germination and persistence. In research trials the oversowing is repeated until successful establishment is achieved.

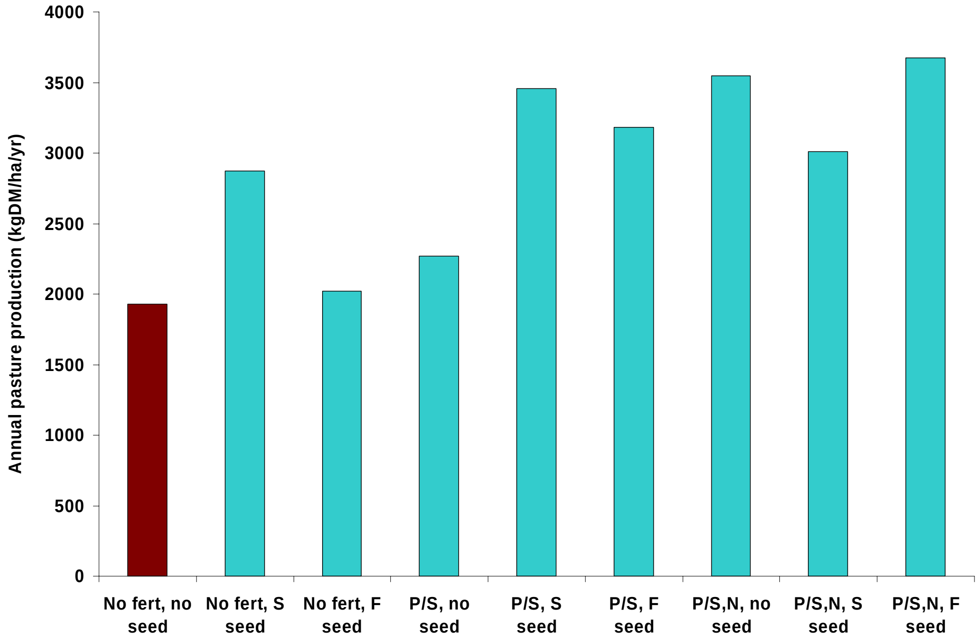
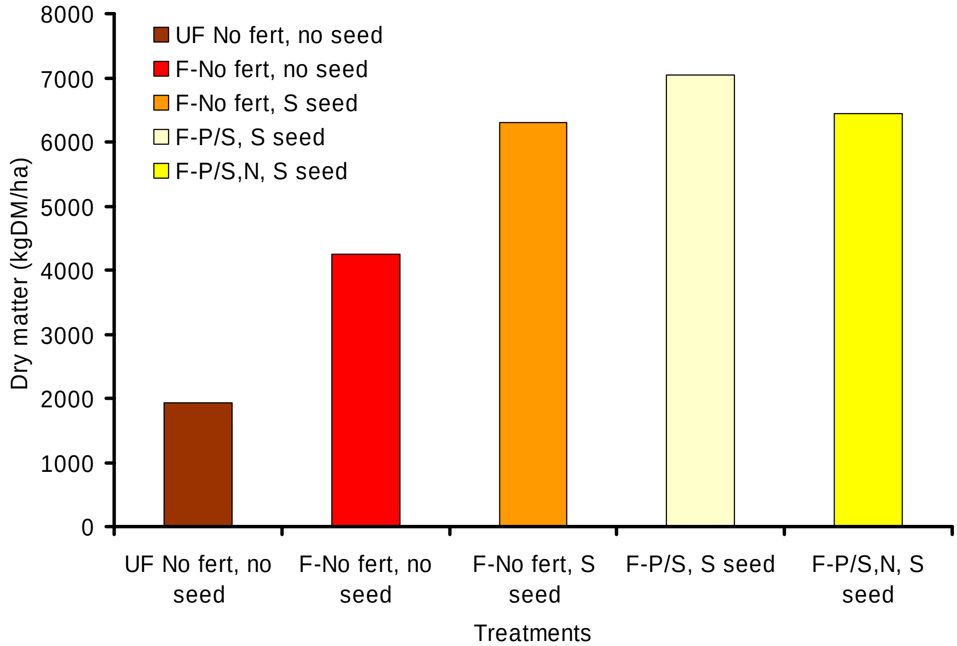


Figure 24: Annual pasture production from 3-5 years on over sown unfenced slips with either Fast (F) or Slow (S) growing seed and fertilised (No fert, or phosphate and sulphur (P/S) or nitrogen (N).



Research on regrassing slips in Wairarapa showed that fencing and slow establishing seed improved pasture production of slips

Figure 25: Annual pasture production from 3-5 years on over sown slips with either Fast (F) or Slow (S) growing seed and then left either unfenced (UF), fenced (F) and fertilised (No fert, or phosphate and sulphur (P/S).

Economics

Economic analyses commonly use a range of assumptions and estimates. Here is a scenario for a 550 ha farm, growing an average of 8000 kg DM/ha, with certain assumptions (Table 7) regarding farm land classes, productive capacity and utilisation of feed grown on these land class, area of slips.

Table 7: Assumptions particular to the farm included in the economic analysis.

	Land Classes On The Farm		
	Flat, rolling	Hill	Steep hill
Farm area (%)	14	51	35
Relative productive capacity (%)	100	80	60
Scar slip area (%)	0	5	15
Utilisation of feed (%)	70	65	60
Gross return from consumed feed (c/kg DM)	15	13	11

This farm has 7.7 % of farm area affected by slips (scarp and middle zones only) and the loss in production relative to non-eroded equivalent land from year 1 to 10 without any remedial action for steep slip areas was 100, 94, 89, 84, 79, 74, 69, 65, 61, 56% (a 100% productive loss means the slope produced no DM, 56% means that the productive capacity of the slope was 44% relative to an non-eroded site). The loss in consumed DM production per ha for the farm is 320 kg DM/ha (4.4%) in the first year and 125 kg DM/ha on the tenth year which equates to $20850 in the first year and $7808 lost income in the 10th year. On just the slip area this equates to lost income of $489/ha on the first year and $183/ha on the tenth year.

Oversowing

Slips will revegetate naturally so an economic analysis of oversowing must examine the marginal increase in revegetation rate after oversowing.

For this brief analysis the following assumptions were made:

- The same farm as described in the section above was used.
- It is assumed that only the slip face is regrassed and tailings are ignored. Both research and the farmer survey do not find any advantage in regrassing tailings as they reseed naturally.
- Three levels of cost of oversowing are examined $85, $160 and $300 which encompass seed type and application methods but doesn't include additional fertiliser.
- Four levels of improvement in revegetation are examined 10%. 30%, 50% and 80%
- Three levels of risk are examined. Regrassing attains levels of improvement of revegetation 30%, 50% or 100% of the time. One of the problems with oversowing is that you are likely to oscillate between complete failure and good effect. Only 30% of farmers regrassing slips gave ranks above neutral when asked to assess effectiveness of regrassing however this may be because they were ranking it against undisturbed ground. The conditions following regrassing were

excellent after the February floods, in another year it could have been more risky.

- The period of accrued benefits was taken at 10 years.
- No appreciable revegetation occurs in the first year irrespective of treatment
- Oversowing improves revegetation rate over first five years, this benefit remains after 5 years but revegetation rate reverts to same rate as found naturally after 5 years.
- Maximum recovery from slip is 85% of productive capacity because soil depth doesn't fully recover.
- Maximum recovery can occur earlier than in natural revegetation (but in most sensible scenarios this doesn't occur within the 10 year evaluation period)

The results of the economic analysis are presented in Figure 27.

At high ($300/ha) costs (e.g. helicopter application of both clover and grass seed) of application a good economic outcome is only possible if you assume a 100% reliable outcome coupled with high rates of improved revegetation. Costs could easily be even higher than this "high" cost scenario if such things as, the use of fertiliser, higher rates of seed application or the use of more expensive species are included; and it follows that increased cost will give poor economic results. This high cost option was the one chosen by most of the farmers for regrassing slips. The risk factors could be minimized and the rates of revegetation could be improved at this high cost level by only regrassing moderate slope slips.

At moderate ($160/ha) regrassing costs (e.g. clover seed only spread by helicopter) moderate levels of risk and moderate rates of revegetation are required to achieve a good economic outcomes. Research shows that legumes have superior performance over grasses on slips. The farm survey shows that clover survives better than grass on slips. There seems little point to including the additional cost of grass seed in the mixture.

Under the low cost option (clover seed spread by hand with no cost of application included) a good economic return is still possible at greater risk levels and lower rates of improvement in revegetation.

Regrassing costs must be kept low to achieve a good economic outcome following regrassing slips

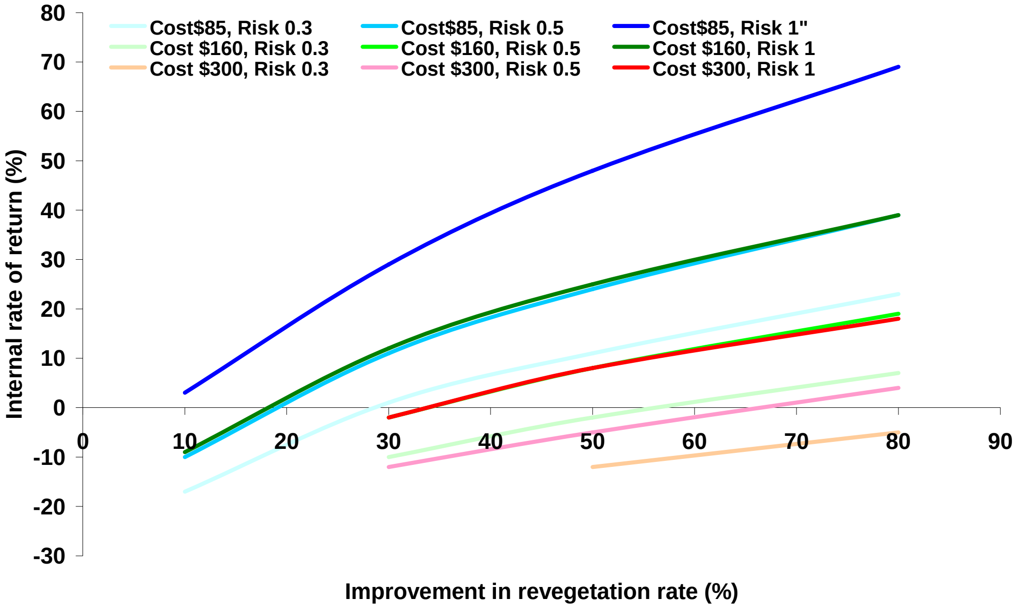


Figure 27: Internal rate of return (interest rate) earned from oversowing assuming varying rates of vegetation given costs of oversowing of $85/ha (clover sown by hand), $160 (clover and grass seed sown by hand), $300 (clover and grass seed sown by helicopter) assuming varying levels of riskiness (1= no risk at all, 0.5= half the time successful, 0.3=successful one third of the time).