Slips: pasture production and revegetation
Technical document for rural professionals

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Summary

It is important to determine the impact of the slips on a farm's total pasture production so likely impacts on the farm system can be assessed. Once the damage assessment to the farm has been established then the economic implications of any responses to the situation can be made. It is the intent of this document to provide information and outline principles to aid farmers to calculate the loss of dry matter production due to slips.

The loss in dry matter (DM) production due to slips can be calculated from the percentage of the farm affected from slips on various slope classes. Slips often occur on less productive steep slopes. Losing areas of steeper slopes will have less impact on the overall farm productivity than losing more productive flats. The scar face is the site of most loss of production whereas tailings below slips are often more productive than surrounding slopes and revegetate quickly. Loss in DM production can be calculated from the proportion of the slip that is scar for a particular slope class. It then has an ability to revegetate itself with time. After 5 years of revegetation with no remedial action DM production on slips is about 20% of non-eroded sites.

The effectiveness of revegetating slips depends on soil depth on the slip, soil fertility, aspect, soil water holding capacity and remedial action taken. In dry hill country fencing or spelling from grazing has the greatest impact on revegetation of slips, followed by reseeding with legumes and then additional fertiliser. However all these actions have a cost which must be weighed against the potential benefits.

Calculating impact of slips on lost consumed DM

To calculate the impact on the farm system of slips in the short and long-term it is necessary to calculate the area of the farm affected by slips. This requires an estimate of the following:

- Scar face:tailing ratio
- Natural revegetation rate of slip
- Productive capacity of the steep slope that has slipped
- Utilisation of feed on the slope

- Quality of the feed grown on that slope.

Scar face vs tailings
Slips typically consist of two distinct areas, each with their own particular characteristics:

- 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.
- Slip debris tailings (or run-out) is where the majority of the slip accumulates as a tumbled mixture of deeper soil and buried vegetation (possibly higher fertility).

The tailing debris will revegetate quickly within 6 to 12 months due to plant tillering through the topsoil, and from dormant seeds already present in the upper soil layer. In some instances subsequent regrowth on these tailings is higher (up to 30%) than equivalent non-eroded slopes. However it is probably prudent to ignore this potential gain in calculations of impacts of slips on pasture production. The base of these slips often poses the greatest risk to stock losses from bogging.

The face 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. Rather different parent material had a consistent face:tailing ratio. Faces percentage relative to slip facing for mud and siltstones range between 20 and 25%, volcanic ashes 30%, sandy siltstones 35 and sandstones 40%.

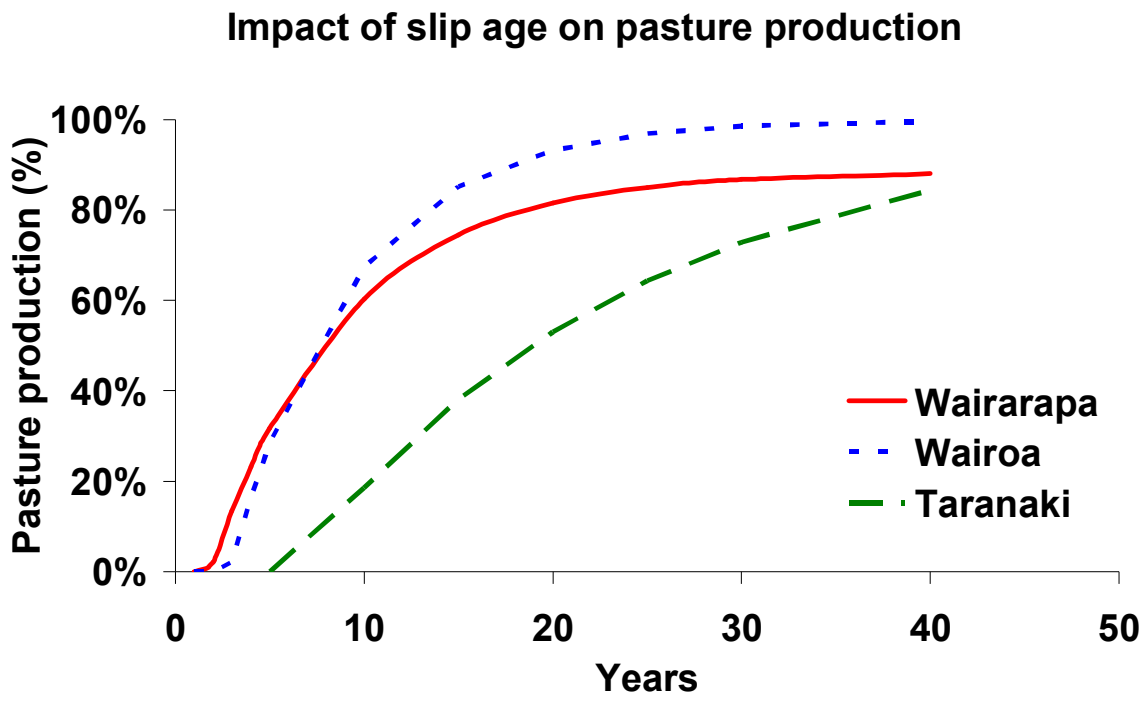
For losses in production you should only consider the slip face. Shortly (this month) Landcare, Research, Agriquality and MWI may be providing many farmers with an assessment of the % of slip damage on the farm for different slope classes and aspects, corrected by ratio of slip to tailings from images taken by satellite. To take the image the region will need to be cloud free at 11 with the right satellite passing at the time (1 day in 4). When cyclone Bola hit New Zealand the average loss of farm area due to scar face averaged between 10-20%. Farmers estimates of the area of farm affected by slipping were 3.7 times higher. If this assessment is being done by eye farmers will need direction in using the right slip face:tailing ratios.

While farmers have been hit with an exceptional major event it is also important to remember slips and erosion occur continuously on our hill country until an equilibrium has been achieved. There will be many sites on farms where old slips have occurred and are now revegetated. However 80-year old slips will still be producing around 14% less than the surrounding non-eroded areas of similar slope.

Natural revegetation rate of the slip
Slip scarps and sometimes the face usually have a shallow subsoil or none at all, low moisture holding capacity, and low organic matter and very low nitrogen status. Slips that have occurred on mudstone soils are likely to recover more rapidly than those on sandstone materials because of the finer material and ability to retain moisture for longer periods. Slips will have different soil fertility than non-eroded areas and separate soil tests will be useful. This information can be used to determine the likelihood of successful oversowing or self-revegetation and to plan future fertiliser applications. However any slip will have a mix of conditions of varying depths of disturbed soil and bare, hard subsoil surfaces.

The slip scar progressively becomes colonised by pasture species and the loss in production continues because of the presence of bare soil and both impaired water holding capacity and fertility levels. It takes 20 years or more for substantial recovery (see Figure below) and, in some soils, full recovery never occurs because soil depth remains less than that of non-eroded sites.

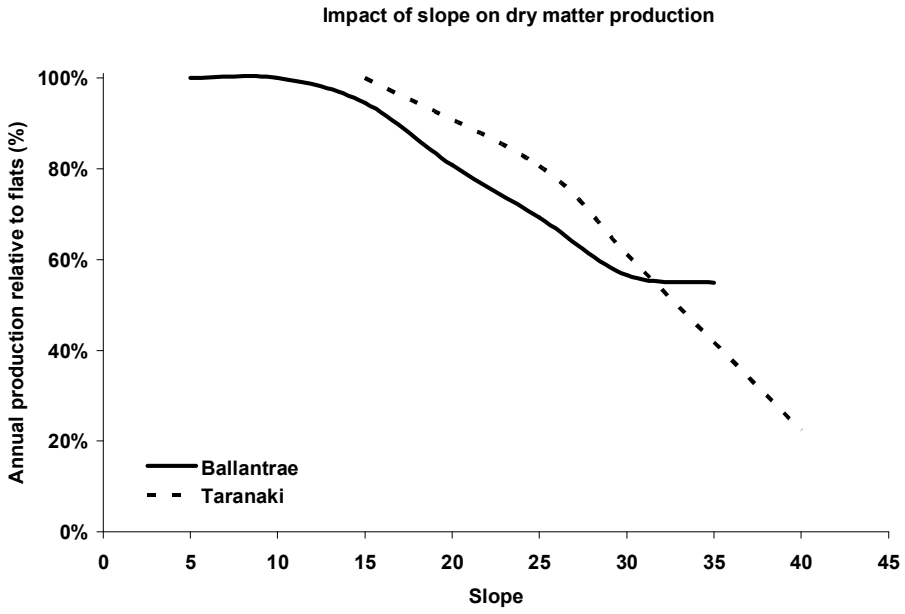
If the slip has removed most of the soil (i.e. down to mudstone or sandstone rock material) pasture recovery will be retarded as shown on the Taranaki (sandstone) graph below. Rock weathering will be required to reform the soil before appreciable pasture establishment can occur. Other slips may still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



Productive capacity of the slope that has slipped

Slips occur predominantly on the steeper (over 28 degrees) slopes and less productive areas where feed utilisation efficiency is also be less than on flats or rolling country. Steep slopes are lower producing than other areas of the farm. This needs to be recognised when assessing the impacts of slips on overall farm pasture production.

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 that the percentage reduction in pasture production as slope increased was similar on both high and low fertiliser treatments and that the reduced production with slope levelled off at 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 derived from an experiment specifically designed to determine the effect.



It is important to note that moderate slip damage often only produces the same loss in dry matter as a poor "growth" year and it is lucky that this year feed covers should be good going into the winter. However studies show that pasture production on slips was more adversely affected in summer (poor water holding capacity) and winter (clover dominance) than in spring and autumn. These normal feed pinches are likely to worsen on farms with significant slip damage.

For example on calculations of the loss of DM see section on economics.

Planning the response
Having calculated the loss in dry matter, a new feed budget and response can be planned. Depending on the outcome a number of farm strategies can be appropriate including culling stock early, bringing forward sale dates of stock, putting on more nitrogen or fertiliser, changing mating decisions, reducing stock classes, grazing off, reduced buying in of stock. It is highly probable that increased expenditure on the stable areas is much more economic than spending money to revegetate slips (see section on economics).

But slips are oversown for a number of reasons only a few of which may be based on sound economic principles. Such reasons include "speeding up the colonisation of the vegetation because I don't like looking at slips" .Others may want to "stop donating even more soil to the waterways". Others may simply be "maintaining the marketability of their farm in terms of real estate". In the scheme of things the small expenditure required to oversow slips is much less than that required to restore tracks, water systems etc. Oversowing if successful will recover the farmer his investment over the medium return with a very modest (in farming terms) return on his investment which given the other social issues outlined above may be quite acceptable to individual farmers.

Remedial action to revegetate slips

There are a variety of actions that can be taken with slips. These range from doing nothing, applying additional fertiliser, oversowing, fencing and revegetation with pasture plants or native or indigenous trees. The type of appropriate remedial action is a complex question depending largely on the environment in which the seed will be placed (soil fertility, depth of soil, soil moisture content) climatic conditions (dryness of summers, likelihood of heavy rain after oversowing, onset of dry conditions limiting establishment, onset of cold conditions after establishment), ability to spell the pasture once sown (ability to rotationally graze and/or cost-effectiveness of fencing slips). It is likely that farmers will probably apply various remedial remedies ranging from zero intervention up to highly costly fencing + oversowing+fertiliser depending on the location and condition of the slip.

Fertiliser
In Wairoa, at medium fertiliser application rates, the slips attained pasture growth rates of only 38% of that on the unaffected slopes, whereas at a high rate of fertiliser applied to slips growth reached 56% of that of uneroded areas. A similar 20% improvement in revegetation was found in Wairarapa hills following fertiliser application. Phosphate and sulphur and possibly lime are important for supporting the legume growth as it develops. Nitrogen will only have benefit once grass species become established.

Oversowing
Timing and what to sow
Oversowing should be done while the slip is still damp and/or when climatic conditions are favourable for seed germination (autumn). Adequate moisture is needed for germination and seedling establishment. IResults from oversowing will be variable. Heavy rain washing seed from the slips and subsequent drought killing seedlings are both risks. The steeper the slope and the shallower the soil, then the higher is the risk of establishment failure. On steep slopes there are few flat sites for the seed to lodge. In the past ledging or terracing across the slope by hand or by using stock to provide sites for seed establishment has proved beneficial. Success will be increased if the area can be spelled to allow good establishment.

Legume seed should be coated as a cheap insurance but *rhyzobia* should be present if clover has been growing on this site. Deep-rooted legumes such as lotus and red clover were effective in the adverse slip environment of Wairoa and Wairarapa. A look around on you're the property in the steep

especially the poor fertility banks will give you a good idea of the best legume to oversow. If sowing white clover, small leafed hill country cultivars would be most appropriate. If the supplies of this clover disappear then Huia could be the next best option. In the summer moist hill country then 6 kg/ha of coated small-leafed white clover is the recommended best practise. On dry slopes subterranean clover (1-3 kg/ha) could be included in the mix. On slip areas permanently removed from grazing then lotus and red clover added to the other two legumes are good options in the mix.

In general terms in the Southern North Island oversowing can occur from March until around mid May, though keep an eye on dropping soil temperatures in May. White clover can germinate down to soil temperatures of 5^{o}C soil but there needs to be time for the seedling to establish and grow before winter. Sub clover germinates at lower soil temperatures than white clover. In summer moist environments there is also a window of opportunity for oversowing from mid August to September. Success of oversowing will be increased if the area can be spelled to allow good establishment.

Two research trials have shown little benefit from the oversowing of grasses onto slip scars. This is probably because there is limited nitrogen available to foster good grass growth. Benefits did occur from oversowing legumes. In Wairoa natural revegetation restored 13% of productive capacity compared to oversowing with lotus and redclover which restored 80% of the productive capacity by the second year. However, it is probable that these slip scars were being lightly grazed because lotus dominance is rare and normally only occurs in the absence of grazing. The results of oversowing in Wairarapa were not as spectacular. In the Wairarapa productive capacity after 3-5 years was increased from 26 to 39% (a 48% improvement in revegetation rate) by oversowing. Monitoring did not continue past these periods so extrapolations over ten years are largely guess work.

Sowing seed

Legumes (and grass seed) may require a carrier agent to aid its spreading. Superphosphate is a suitable mixing agent but it must be mixed immediately before flying on because the superphosphate could kill rhyzobia on uncoated seed and may burn the seed if left too long. Slips can be oversown by plane (only suitable for large area of slips), helicopter or by hand.

Plane: An aircraft will cost around $650 per hour and will cover somewhere between 10 and 30 ha/hr of slip depending on the turning time so will average $20-$65/ha. Planning it out before hand and trying to get long runs together will reduce plane time and save money. The plane will lack precision for small slip areas and is more suitable for large areas. It is likely that a carrier agent will be required.

Helicopter: The helicopter can be used to apply seed precisely and at rates down to 10 kg/ha without a carrier. Cost will be around $1200/per hour and will incur a minimum charge of around $500. Coverage is in the order of 20-50 ha/hr. Buckets carry about 300 kg of seed. Cost savings can be made by groups of farmers getting together to oversow at the same time.

By hand: This will obviously be very time consuming but is cheaper and seed can be dropped in places with the greatest chance of establishment. Dry river sand is a good blending agent to mix with the seed to aid even spreading. Once the infra-structure has been restored on the farm it could be a good job for students, local kids, or people offering to help.

Fencing

Spelling the slip from grazing allows the pastures to establish and is the most effective (though not necessarily cost-effective) means to return the slip back to potential production as quickly as possible. In reality it is totally impractical and probably shouldn't be discussed with farmers. There may be some instances when a whole paddock is spelled and maybe even removed from grazing on a temporary or long-term basis.

Average productive capacity 3 to 5 years post slip was increased from 26 to 57% (improvement in rate of revegetation by 119%) by fencing in the Wairarapa. However the slip areas are spelled and this DM is not available for grazing. Fencing can also allow the planting of trees to help stabilise the slope and minimise future damage.

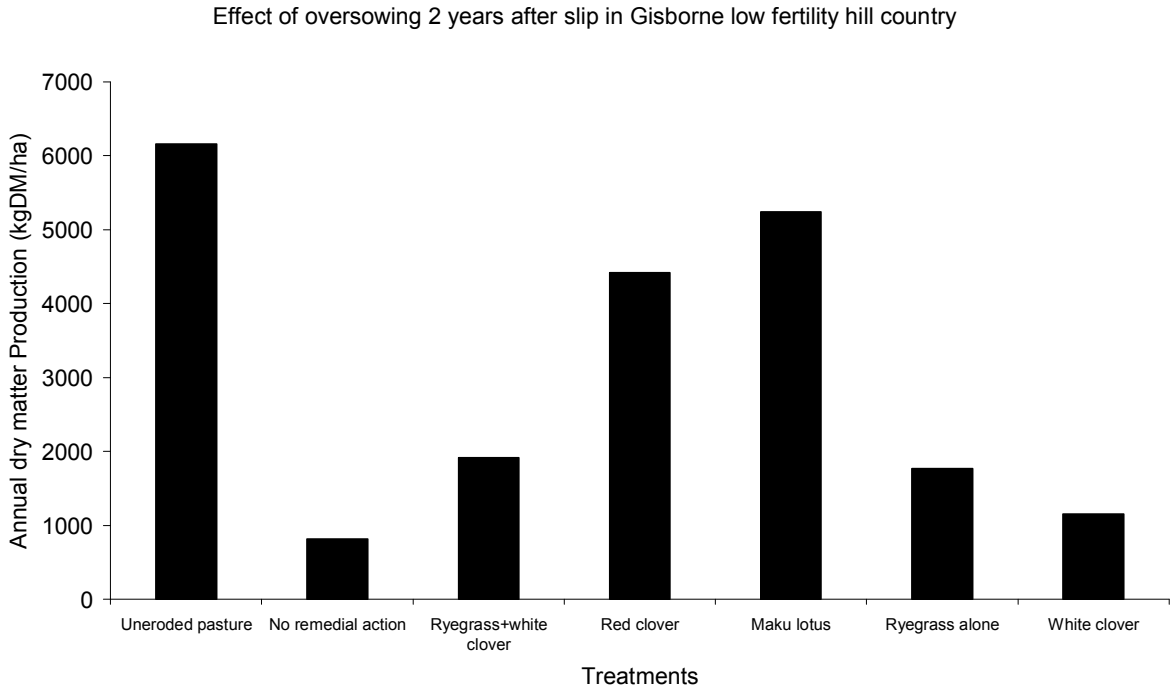
Some farmers have temporarily fenced off slips using shade cloth. Care should be taken to insure that the slip is stable before fencing. Single wire fencing with cattle grazing and intermittent grazing with lambs is also an option but no information is available on it's effectiveness. With fencing with 5

wire electric fencing then about a 400% improvement in the rate of vegetation is required before a reasonable return on investment is achieved.

Research results

Experiment one

In Gisborne post Cyclone Bola research was conducted on 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 mix with ryegrass had little effect on revegetation of slips in low fertility hill country. Maku lotus and red clover were the most successful legumes to oversow for fast slip coverage (see below).



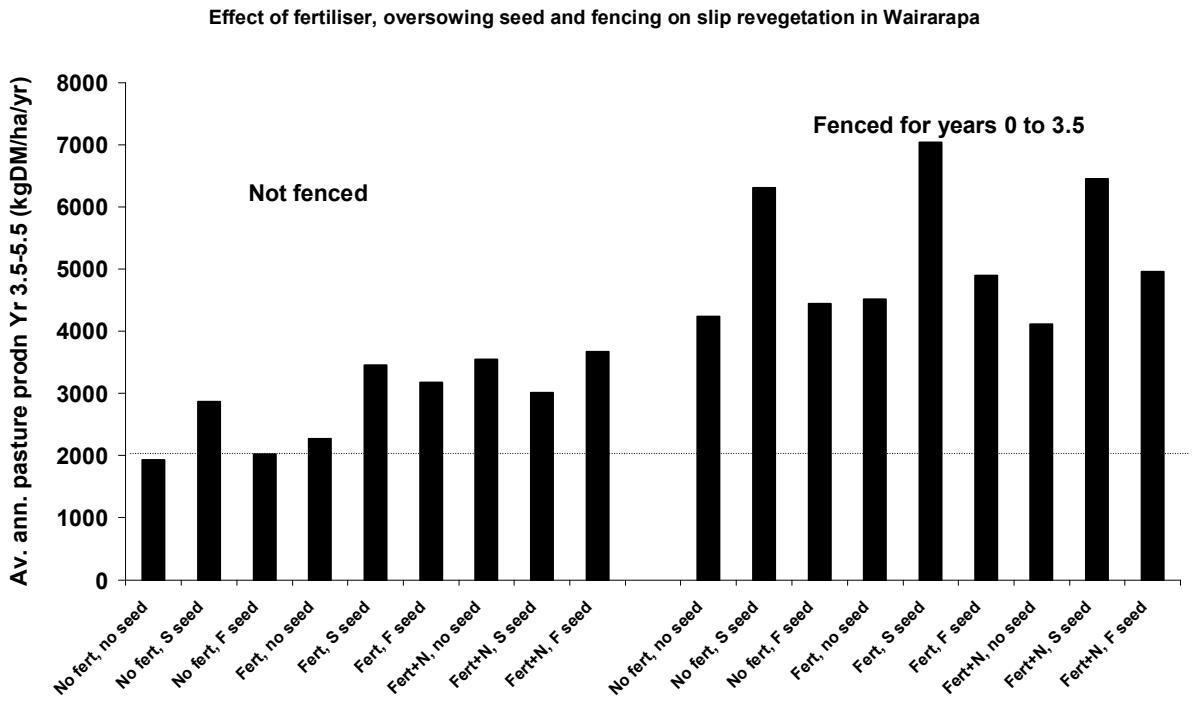
Experiment two

The 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 slips and was 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.

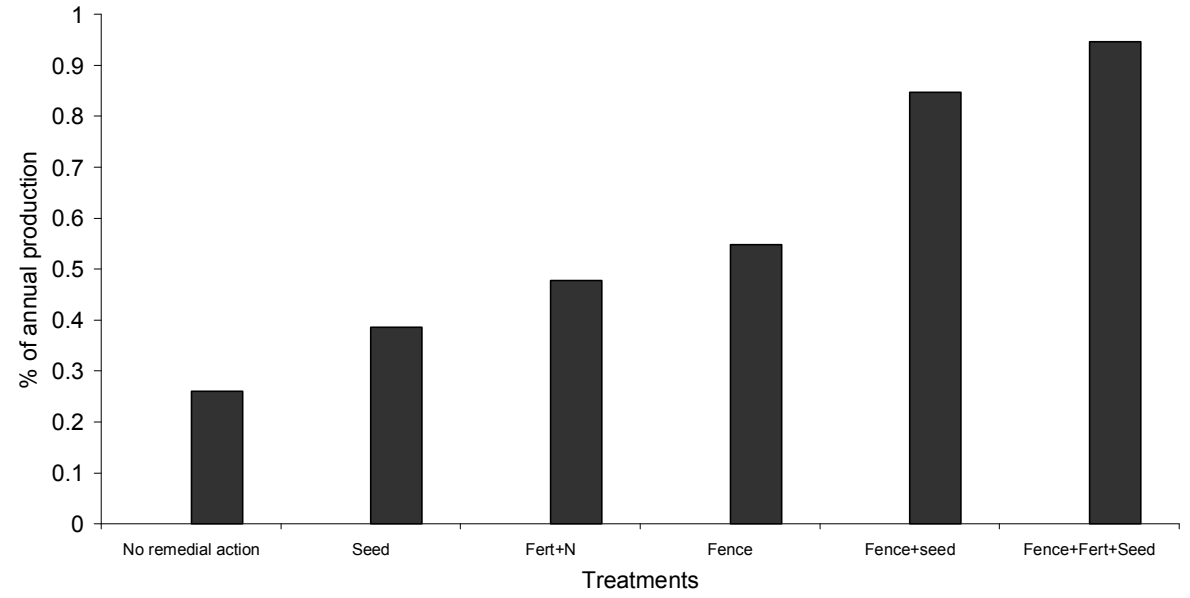
Fertiliser treatments were no fertiliser, 250 kg/ha S-superphosphate annually, and S-superphosphate plus 100 kg N/ha annually.

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).

Fencing: Half the scars were *fenced* to exclude grazing livestock for $2^1/_2$ years.



Effect of remedial action on slip dry matter production 3-5 years after slip relative to uneroded site in Waiarapa



In the first $2^1/_2$ years bare ground decreased more rapidly on the fenced than the unfenced areas, and this was hastened by seed application; fertiliser N increased the amount of plant material/litter on the slips.

In the first $2^1/_2$ years white clover (average 25% content) and lotus (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. Yorkshire fog (average 8% where sown) and cocksfoot (average 6% where sown) 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); was not influenced by fertiliser treatment or fast-establishing seed application; and slow-establishing seed application increased production 40%.

Pasture production was greatest where strong white clover and lotus establishment had occurred – in fenced areas, where slow-establishing seed had been applied, and where N was not applied.

Farmer helpful hints

- Holes in fences can be temporarily and quickly filled with shade cloth
- If farmers wanting to reuse fencing material need to extract them from the mud before it hardens
- Be astute with your timing of any oversowing, it is crucial. Different aspects respond differently.
- Get the helicopter to drop off fencing material around the farm while it is on the farm to oversow slips.
- Use Task force green if you get the opportunity.

Economics

Every economic analysis uses a myriad of different assumptions all of which can be debated. Some of the assumptions used here had to be made without any data on which to base the assumptions (eg. effect of oversowing on long-term slip recovery).

One possible scenario is for a 550 ha farm, growing an average of 8000 kg DM/ha and with the following assumptions regarding farm land classes, productive capacity and utilisation of feed grown on these land class, area of slips and outline below.

	Land classes on the farm		
	Flat, rolling	Hill	Steep hill
Farm area (%)	20	40	40
Relative productive capacity (%)	100	80	60
Scar slip area (%)	0	0	15
Utilisation of feed (%)	70	65	60
Gross return from consumed feed (c/kgDM)	13	11	9

This farm has 33 ha of slip and the loss in production relative to uneroded 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 uneroded site). The loss in consumed DM production per ha for the farm is 216 kgDM/ha (4.4%) in the first year and 212 kgDM/ha (2.5%) on the tenth year which equates to $10 700 in the first year and $6000 kgDM/ha lost income in the 10th year. On just the slip area this equates to lost income of $324/ha on the first year and $182/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.
- Cost of oversowing (seed + application) $100/ha
- 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)

Providing the rate of revegetation is improved by 50% (the rate achieved in the Wairarapa) then oversowing recoups cost with some return but it is much less profitable than putting extra nitrogen (often in excess of $2.5 return for each $1 spent) on each year. If the cost of oversowing was $150/ha this reduces the IRR at 50% improvement in vegetation rate to 11%. The problem with oversowing is that you are likely to oscillate between complete failure and good effect rather than achieve "average effects" and there is no information of the frequency of success and failure and hence risk.

But slips are oversown for a number of reasons only a few of which may be based on sound economic principles. Such reasons include "speeding up the colonisation of the vegetation because I don't like looking at slips". Others may want to "stop donating even more soil to the waterways". Others may simply be "maintaining the marketability of their farm in terms of real estate".

	Percentage improvement in revegetation rate following oversowing				
		20%	50%	0	200%
Productive potential of slipped paddock at year 10 relative to uneroded slope	44%	48%	54%	60%	85%
Net profit (costs-marginal benefit)	0	-85	5034	10 100	30 500
Internal rate of return (%)	0	0	19	32	70

Highly recommended reading

Soil Conservation: Technical Handbook. ISBN:0-478-24033-3. Published The Ministry for the Environment Wellington. Available on the web.
http://www.mfe.govt.nz/publications/land/soil-conservation-handbook-jun01/index.html

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Resource material

Handout material for farmers is attached and provided as a PDF file.

A poster is available on request from Johanna (with at least three days notice) 06 351 8156. Cost approximately $60. Poster is provided as PDF file as well.

Slips: pasture production and revegetation
Handout material for farmers

Once a farm has been hit with slips then the first priority must be to look after the home and family. Second is the need to get access to the farm. Tracks are roughly cleared to allow access to the farm and left to be tidied up later when the soil hardens. Gaps in fences are fixed and wandering stock are found and put back into stock-proof paddocks. Once a breathing space occurs the impact of slips on the farm business can be explored.

Firstly it is important to try and assess the overall loss in production that has occurred as a result of slipping. Slips are made up of face and tailings. The face is where the soil has been removed leaving a shallow soil with low moisture holding capacity and little organic matter and very low nitrogen levels Faces are slow to revegetate. However, the face makes up only about 30% of the visible slip damage. The soil that was lost from the slip is found in the tailings. The tailings are a tumbled mixture of soil and buried vegetation. The tailing debris will revegetate within 6 to 12 months due to existing plant material and from dormant seeds already present in the upper soil layer. In some instances subsequent regrowth on these tailings is higher than equivalent non-eroded slopes. It is appropriate therefore to only consider the slip face as "lost" dry matter.

When calculating the immediate loss in dry matter, estimate the percentage of slip face and the steepness of the slopes involved. Slips often only occur on the steeper slopes (>28 degrees) which only have 60% of the productive capacity of flat/rolling country. Both pasture utilisation and quality is also lower on these steep slopes. It is possible over the next month (depending on cloud cover over the region at 11 am) that all farmers with more than 2% slip face damage on their farm will receive a satellite image indicating the area of slip face damage on their farm. Alternatively the damage can be visually assessed from the ground.

Estimated loss in consumable dry matter as a result of varying slip damage on a Central North Island farm of average topography (27% flat/rolling, 48% hill and 27% steep hill)

%slip face on hills	0	2	3	5	8
% slip on steep hills	3	9	15	25	42
Loss in annual consumed dry matter (%)	0.6	2.6	4.2	7	11.7

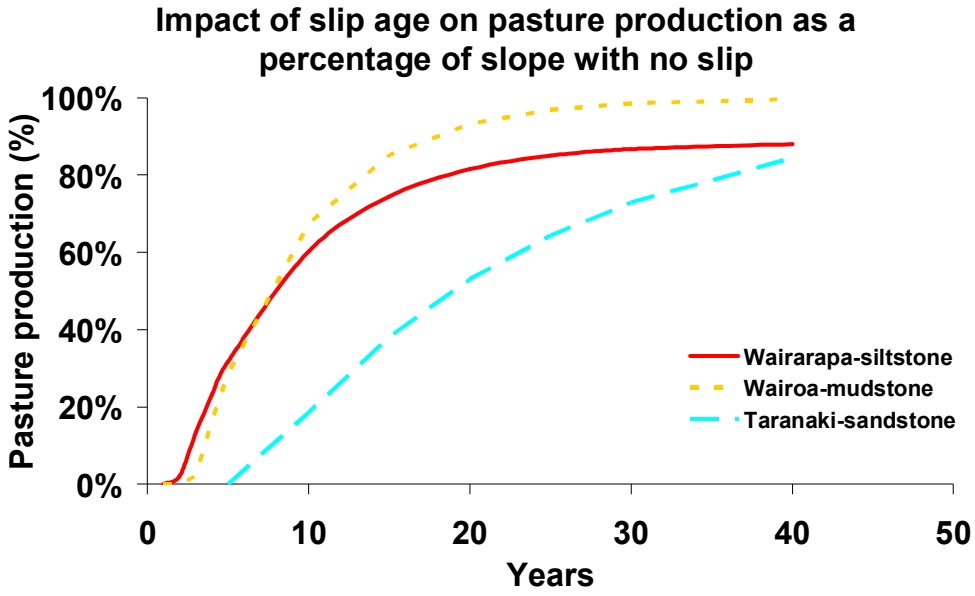
It is important to note that moderate slip damage often only produces the same loss in dry matter as a poor "growth" year and it is lucky that this year feed covers should be good going into the winter.

Having calculated the loss in dry matter, a new feed budget and response can be planned. Depending on the outcome, farm strategies may include culling stock early, bringing forward sale dates of stock, putting on more nitrogen or changing mating decisions. It is probable that increased expenditure on the stable areas is more economic than spending money to revegetate slips.

But slips are oversown for a number of reasons only a few of which may be based on sound economic principles. Such reasons include "speeding up the colonisation of the vegetation because I don't like looking at slips" .Others may want to "stop donating even more soil to the waterways". Others may simply be "maintaining the marketability of their farm in terms of real estate".

The slip scar will naturally revegetate over time becoming colonised predominantly by legumes and low fertility tolerant pasture species. As time passes the amount of bare ground gradually disappears but soil is only slowly reformed. The shallow soil is prone to drying out and is not fertile. It takes 20 years or more for substantial recovery (see Figure below) and, in some soils, full recovery never occurs because soil depth and organic matter content remains less than that of non-eroded sites.

But it is important to realise that while you have been hit with an exceptional "slip" event, slips and erosion occur continuously on our hill country. There will be many places on your farm where old slips have occurred and are now revegetated.



If you choose to oversow slip faces then there are a few guidelines that should be followed to improve your chance of success. Firstly it is essential that you use coated seed. Secondly, put the seed on at a time that gives the seed the greatest chance of germinating and establishing in the hostile slip environment. There is a risk of losing seed or seedlings either due to heavy rain and/or subsequent dry periods. Establishment can also fail if the slip has not stabilised properly. The risk of establishment failure will be greater on slips that are steeper and those with little residual soil. Slips arising from mudstone parent material will be easier to revegetate than those from siltstone, and sand-stone based soils will be the hardest of all.

Legumes have the greatest chance of colonising the low nitrogen environment that exists on slips. On the intensively grazed, fertile, summer moist, hills of the Manawatu, Taranaki and Rangitikei districts small-medium leaved “hill-country” cultivars of white clover should be the most effective legumes for slips recovery. Around 6 kg/ha of coated innoculated white clover seed should be sufficient though higher rates will result in greater plant numbers but at a greater cost. Seed is flown up the slips by a helicopter (approximate cost white clover + helicopter $100/ha). The helicopter costs will be cheaper if a group of neighbours get together to sow slips. On dry slopes subterranean clover could be included in the mix. On slip areas permanently removed from grazing then lotus and red clover added to the other two legumes are good options in the mix.

In general terms in the Southern North Island oversowing can occur from March until around mid May, though keep an eye on dropping soil temperatures. In summer moist environments there is also a window of opportunity for oversowing from mid August to September. Success of oversowing will be increased if the area can be spelled to allow good establishment. In the few trials, oversowing has been shown to add about 1500 kg DM/ha/yr to the productive capacity of a slipped area over the first few years after slippage.

Once a slip face has recovered some vegetation, phosphate and sulphur and possibly lime will be important for supporting the legume growth as it develops. In trials, fertiliser boosted the benefit of oversowing by a further 600 kgDM/ha. However the normal farm fertiliser applications that occur in the modern era should be sufficient to support growth on slips. Nitrogen will only be of benefit once grass species become established.

There may be areas of slips that would benefit from tree planting. Highly recommended reading for soil erosion control can be found on this website http://www.mfe.govt.nz/publications/land/soil-conservation-handbook-jun01/index.html

Information contributors: *This information has been compiled on behalf of MAF sustainable farming fund and Meat and Wool New Zealand using information provided from experienced farmers, researchers from AgResearch and Massey University and rural professionals from Greenfield’s Communications, Dexcel, Wrightsons, Ravensdown, Agriseeds, Agricom, Balance, QuinPhos, Agricom, Pioneer, Hills Laboratory, Wilsons and Keeling, Horizons Regional Council, Pyne Gould Guiness, Williams and Kettle.*