Part B
Practices

Contents – Part B

Tables

Surface Erosion control

Chapter

1. Cropland Management

2. Pasture Management

3. Fencing Management

Cropland Management for Surface Erosion Control

1.1 Introduction

These management practices encompass conventional tillage, minimum tillage, no tillage, stubble mulching and contour cultivation. Runoff management practices for arable land are described separately (see 10).

It is important to understand the terminology used with respect to cultivation, minimum tillage and direct drilling in NZ.

- Conventional Tillage – Is the practice of establishing a crop or pasture in the field which has been tilled or cultivated. (Includes the full cultivation process to seed bed stage).
- No Tillage – To establish a crop or pasture where no cultivation is carried out at all. This term is synonymous with Direct Drilling.
- Minimum Tillage – is where the soil surface may have only one or two passes over it by using say harrows or light discing then sowing the seeds (rather than full cultivation process).

It is important to note that most cultivation equipment will mechanically move soil downhill leaving upper slopes and knobs bare of soil. Erosion greatly speeds up this movement, which can be clearly seen on paddocks that have been ploughed one way for many years.

1.2 Conventional tillage

1.2.1 Guidelines

Many farmers prefer conventional tillage with a plough, prior to seedbed preparation with harrows or discs. Downslope soil loss can be reduced by the following practices:

- Cultivating on the contour where possible
- Maintaining slow tractor speed reduces the distance soil is moving downhill
- Travel slower across steeper faces and if going downhill on gentle slopes using rotary hoe, maxitill or grubber (as this equipment can move a wave of soil downwards if travelling at speed)
- Cultivating at the correct time i.e. when soil is moist and friable to minimise the number of passes required
- Use a reversible plough to throw the furrow uphill
- Use other equipment that will have the least impact i.e. paraplow or Maxitill in preference to rotary hoe (i.e. over-use of a rotary hoe will damage the soil structure)
- Where possible use single pass cultivation with multiple implements attached, or a one pass cultivator; may need higher HP tractor or alternatively use a contractor with the specialised equipment
- Judicious use of suitable herbicides may reduce the number of passes required
- Where possible avoid cultivating slopes over 13 degrees especially if the slopes are longer than 30 metres
- Minimise the bare ground by timing the tillage operation (consider rotation type and cover crops)
- Avoid leaving a fine seedbed (surface roughness is vital with a range of aggregate sizes which will promote better infiltration thus reducing the surface runoff and erosion).
- Take care to minimise compaction from machinery by not cultivating in winter months, or when the soil is wet in spring and autumn
- Leave dry, ephemeral watercourses uncultivated i.e. in permanent pasture – Refer to Grassed Waterways.

Steeper area in poplars – no fencing. Cultivation on more gentle sloping land.
Photo: M Harris.

- Plant steeper vulnerable slopes in trees and fodder banks.

Finally if cultivation is deemed to be a necessary practice on the farm then it is vital that ongoing monitoring of the soil aggregate stability is carried out e.g. by visual soil assessments, Shephard (2000).

1.3 Minimum tillage

This tillage practice has been used in New Zealand for many decades, more so before direct drilling technology was mastered. There has been a significant move into minimum tillage in the areas of New Zealand commonly affected by droughts i.e. the eastern side of the South Island (especially after the drought of the eighties and late nineties), also Wairarapa and Hawkes Bay in the North Island.

Minimum tillage may involve using simple cultivation equipment and passing over a paddock only once or twice e.g. with harrows then broadcasting or drilling the seeds. The more common approach today is to use an approved herbicide to reduce the vegetative top cover thus reducing the energy (i.e. fuel used) and machinery passes to prepare a seedbed.

There are advantages over direct drilling, such as minor levelling of a paddock and generally lower cash costs and machinery lasting longer.

1.3.1 Guidelines for minimum tillage

Aim to only carry out sufficient cultivation to prepare the paddock for drilling (use suitable equipment as a maxitill or one way pass cultivator)

- Leaving a rough cloddy seedbed and cultivate to a shallow depth.
- Use approved herbicide to kill existing vegetation (may need two sprays depending on weeds present) this also helps the ground break up, conserves soil structure and moisture. Note that if the soil structure is fine with poor aggregates then it is preferable to direct drill
- On slopes of 13-20 degrees, minimum till only when coming out of long term pasture. If sowing Brassicae crops then include suitable grass species in the mix for good ground cover
- Take care not to get wheel compaction on clay soils

1.4 No-tillage cultivation

Modern technology developed in New Zealand has provided sophisticated coulter designs such as the “cross slot drill” which have eliminated many of the earlier problems and variable results with traditional drills when sowing pasture and crops.

Some of the benefits of direct drills compared to cultivation can be summarised as follows:

- Minimal surface erosion of topsoil
- Soil improvements as the soil structure is preserved and improved whilst leaving pasture and crop residues including stubble on the surface
- Enhances earthworm numbers and other soil fauna
- Fewer new weeds introduced
- Time savings in the number of passes
- Fuel conservation up to 80% less fuel used and lower machinery costs
- Reduced nitrogen mineralisation and carbon oxidation to the atmosphere

Such cultivation systems are already well established in many countries, such as the USA and Canada, and parts of Europe. The benefits and several of the risks have been described in books such as “No-Tillage – Science and Practice” by C J Baker, K E Saxton and W R Ritchie (1996), and “Successful No-Tillage – Practice and Management” by W R Ritchie, C J Baker and M H Hamilton-

Manns (1998. In addition, the North Otago Sustainable Land Management Group has a very useful overview of "Direct Drilling and Pesticide Use" at www.noslam.co.nz/info_sheets/directdrilling.shtml See also "North Otago Sustainable Land Management Guidelines, produced by Otago Regional Council, (1995)".

Choice of drill

In general, the more recent the design of direct drills, the better the results. New triple disk designs with small press wheels give better results than older designs. Triple disc drills perform best when moisture conditions are good, or in sandy or stony soils.

1.4.1 Tips for successful direct drilling

The following steps are recommended for successful direct drilling:

- Test soil well in advance. If lime is required, put it on 6-12 months prior to drilling. Identify run out paddocks in May/June.

- Spray old pasture while soil moisture levels are reasonable and when the pasture and weeds are actively growing, usually between September and November. An excellent plant kill is essential – seek good advice on correct chemicals.

- Where moisture retention is a problem, use the double spray – fallow technique to improve moisture availability. Trials have shown that up to 12 times more moisture is retained to 20 cm depth compared to unsprayed sites. Old pasture killed with herbicide [or other measures], followed by fallow for at least 6 weeks, does not transpire and thus retains soil moisture. Plant roots also break down.

- Inspect newly drilled paddock every 2-3 days while seed is germinating and seedlings are becoming established; take action if insect, slug or weed problems occur.

- Correct timing. If you can wriggle a pocketknife into the soil up to the end of the blade, soil conditions should be suitable for direct drilling. If not, it is either too dry, or the roots have not broken down sufficiently.

- Do not direct drill when conditions are too wet. Smearing of soils can result if conditions are not suitable; this will drastically affect germination.

- Best sowing depth. Sow no deeper than 13 mm for most seeds. If sown deeper, the establishment rate for most pasture plants will drop sharply.

- Harrowing, if the drill used did not have its own press wheels, harrowing helps to produce loose soil to cover the seed in the slots, but be very careful to avoid soil compaction at the seed slots. That would also reduce the establishment rate of the pasture plants.

1.4.2 Results of direct drilling

Ross (2000) found that soil organic matter levels in the top 20 cm under long-term (21 years) no-tillage in the Manawatu were maintained at 85-94% of those under permanent pasture. This compared with a decline of 40% in soil carbon after 17 years of cropping by tillage. Total weight of earthworms under long-term no-tillage cropping was 77% of that under pasture, which compared with a 99.8% decline under 29 years of tilled cropping. The aggregate stability of the no-tilled soil was 85-92% of that under pasture, and five times better than that after 23 years of continuous cereal cropping by tillage. Over the years no-tillage soil became progressively easier to drill (requiring decreasing levels of tractor power) which has been explained by the soil's increasing crumb structure and aggregate stability. Such an observation has since also been confirmed in Canterbury (D, M and A Redmond; R and M Scott; D Ward, pers. comms (1999), in Baker (2000) b).

1.4.3 Pest monitoring and management

During conventional cultivation, plant pests may be mechanically damaged or more easily found by various birds, such as gulls and starlings. With a direct drilling programme, this does not occur and the risk of pests damaging crops increases. Control is possible, but it does increase the use of chemicals. But there are a number of practices that can be used to minimise the use of chemicals in the pest control programme.

Recommendations for pest monitoring and management are:

Grass grub

Dig 10-15 inspection holes across a paddock. If there are more than two grubs per spade square, insecticide should be used.

Springtails

Springtails damage brassica crops soon after sowing, often before seedlings emerge. To establish if springtails are likely to be present at damaging levels, place a white handkerchief on the soil in the afternoon, seven days after sowing. If more than five springtails have jumped onto the handkerchief after 2-3 minutes at ten sampling points across the paddock, then damaging levels are probably present. But spray only if springtail levels are high enough.

Argentine Stem Weevil

Argentine Stem Weevil [ASW] affects all improved pasture and damages by larval feeding and stem mining. ASW resistant ryegrass "high-endophyte" varieties have been developed but the endophyte, a living fungus inside the grass, produces toxins which can lead to animal health problems. Biological control is available in the form of the parasitoid wasp Microctonus hyperodae. But Taranaki Regional Council expects that it will take 5-10 years for this parasitoid to build up and disperse to become an effective control agent of ASW. Assuming that 50% parasitism of ASW is then achieved, a 6% increase in pasture DM production could be expected (TRC Land Management Information Sheet No. 9). Contact the Regional Council or AgResearch for assistance.

Slugs

Slugs are a problem in wet conditions or where there is lots of trash. They are of particular concern to seeds and emerging seedlings of direct drilled crops because the drill slots provide favourable conditions for slugs. Problems with slugs can occur when numbers exceed 15 per m^2.

Steps to take before sowing: Place 5 wet jute sacks diagonally across the paddock, three weeks before sowing. Cover the sacks with pegged down plastic to prevent them from drying out. If there is an average of more than nine slugs under each sack after two nights, slugs are present at levels that may damage the seedlings. Mob stocking at 500 ewes/ha for three consecutive nights prior to herbicide application can achieve good control of such slug populations.

Steps to take after direct drilling: Inspect drill slits two days after sowing. If there are more than four slugs per metre of row, then immediate use of slug baits is recommended, with the following options:

- Thiodicarb pellets @ 7.5 kg/ha if rain is imminent
- Methiocarb pellets @ 7 kg/ha immediately after rain
- Methaldehyde pellets @ 20 kg/ha immediately after rain.

The establishment of "beetle banks"

The establishment of "beetle banks" to maintain habitat for insect predators and to reduce the use of chemicals is recommended. When cultivating paddocks, create a ridge 0.4 m high and 1.5-2 m wide within the paddock. Leave a gap about 25 m at each end to allow farm machinery to move around it. These areas will accumulate vegetative material and provide habitat for insect predators, which will assist in keeping insect numbers down. As a guideline, a square 20 ha paddock (450 x 450 m) will only need one ridge in its centre to ensure adequate coverage by insect predators. The beetle banks will take two to three years to become effective forms of insect control.

1.5 Stubble retention

Prudent farmers try to retain the stubble of the previous crop as a form of wind barrier, rather than burning the stubble, which is still practised by many. A research team at Crop & Food Research Ltd [Team leader Dr Prue Williams] is developing sustainable management systems for arable and horticultural lands and is studying amongst others what happens to the carbon in crop residues under various cultivation treatments [Glyn Francis et al.]. Crop & Food carried out a review on crop residues for the Foundation for Arable Research, Lincoln in 1996 (Dr Patricia Fraser, pers. comm.) but a copy is not yet to hand.

Evidence is mounting that all forms of cultivation oxidise soil carbon and recent US data suggest that the entire carbon content of a preceding wheat crop can be oxidised in 19 days following planting

Ripping compacted wheel tracks.
Photo: Franklin Sustainability Project.

(Baker, 2000 b). Under regular cultivation, soil structure deteriorates, and thus the soil becomes more susceptible to surface and wind erosion. But with stubble retention and less cultivation, humus build-up occur at a rate depending on local soil and climate factors, and soil moisture is retained, especially in the top 300 mm of the profile, which leads to improved infiltration and crop yields (Baker 2000 b). He quotes Anon. (1994) who reported that when soil organic matter content is increased from 2% to 6%, a 65% increase in available soil water results. And that Triplett et al (1968) had found that no-tilled corn with 70% residue ground cover significantly out-yielded conventional corn, but with 45% residue cover, there was no difference between treatments.

1.6 Strip or Contour Cultivation

In the USA, cropping lands prone to wind erosion are generally strip-cultivated, i.e. strips of vegetation, "grass hedges" are kept between areas that are cultivated and cropped. Those hedges act as major catchers of wind eroded soil, and of nutrients in surface runoff (see e.g. Eghball, Gilley, Kramer and Moorman 2000). Such "mini shelterbelts" have been evaluated in the Hawke's Bay by its Regional Council since the mid 90's (D Bloomer, pers. comm.), especially in asparagus growing regions. The HBRC brochure "Sustainable Land – Asparagus Strip Cropping" (May 1996) recommends strips of oats sown in mid June-July at 120 kg/ha over every second asparagus bed. The crop is sprayed off in end August at least 3 weeks before asparagus harvesting starts. In a season that lacked the typical strong Norwesters, the cost saving through lack of windblast to the asparagus spikes was valued at $750/ha. The total cost of establishing and spraying the oats hedges was $229. Asparagus pickers commented that harvesting conditions had improved as a result of increased shelter and minimal dust problems.

1.7 Ripping of wheel tracks

Wheel tracks are a key zone for initiation of surface runoff and erosion within paddocks. They are highly compacted, so have infiltration rates. They also collect runoff from higher ground and channel it. Various trials have demonstrated that cultivation or ripping of wheel tracks markedly increases infiltration and significantly reduces soil erosion.

Wheel track ripping, using a shallow tyned implement towed behind a tractor, should be carried out as soon as possible after planting.

1.8 Cover Crops

A cover crop is grown to be ploughed into the soil rather than harvested at times of year when a paddock is not used to grow vegetables. It stabilises the soil against erosion, adds organic matter, improves soil structure, and uses residual nitrogen from previous crops. By improving soil structure, cover crops help retain high infiltration rates. Commonly used cover crops on granular loams include greenfeed or Massif oats, ryegrass, Phacelia and mustard.

1.9 Fallow

At some stage it will be necessary to leave the soil fallow. The most effective measure to minimise erosion risk in this situation is to plough a cover crop back into the ground. The plant residues add dry matter to the soil, which helps bind it together. Other effective measures are to leave the soil in an open and loose condition, or form ridges using a tyned implement with only a few tynes.

1.10 Soil structure maintenance

1.10.1 Introduction

Retaining or improving soil aggregate structure and stability helps reduce surface erosion by sheetwash and windblow. Aggregate size and stability are important factors because a coarse structured, stable aggregate is relatively hard to mobilise but is quickly deposited when runoff/wind velocities decrease. A fine textured soil that easily breaks down to even finer sized particles is more easily mobilised by runoff or wind, and is more difficult to retain or settle out. Aggregate size influences soil transportability and is in turn influenced by aggregate stability. Both are affected by:

- Natural physics and chemistry of the soil type,
- Amount of organic matter in the soil,
- Type and frequency of cultivation.

The structure of most soils declines under cultivation and recovers under pasture. Soil structural degradation adversely affects cropping. Good soil structure leads to lower tillage costs, more days when the soil is suitable for cultivation, better seed germination, emergence, plant growth and vigour, and higher crop yields.

The type of cultivation equipment used can have a significant effect on soil structure. Machinery passage itself will physically alter soil structure. Rotary cultivators generally produce finer seedbeds than do ploughes, discs or tyned implements. The rate of change in structure stability is dependent on the soil type and on the cropping system. Long term, continuously cropped soils require more cultivation passes to produce a fine seedbed and are therefore more susceptible to erosion, than are paddocks with short-term cropping, no-tillage cropping, or a pasture cover.

There is a strong relationship between aggregate stability and soil organic matter. Cultivation exposes more soil surfaces to aeration and this increases the decomposition of organic matter by soil organisms. This loss of organic matter contributes to loss of soil structure and reduces the ability of the soil to recover. Organic matter is conserved with minimum soil disturbance and maximum residue input, such as occurs under a no-till system.

1.10.2 General guidelines (from Shepherd et al 2000)

Minimum or no-tillage cultivation systems should be utilised. These avoid or minimise cultivation and minimise structural damage. Surface residue increases organic matter and therefore soil structure. Aggregate stability is significantly higher under these tillage systems than from cultivated cropping.

Cultivation should be undertaken at the correct moisture levels. Cultivation when soils are too wet causes smearing and thin plough pans that reduce infiltration.

Cultivation implements that minimise structural damage should be selected. These avoid, or minimise, cultivation and therefore minimise structural damage.

Practices that avoid compaction of the soil should be used. These include using low ground-pressure machinery (wide tyres, tracked equipment etc); minimising traffic (by reducing cultivation runs; planning the paddock layout etc); and cultivating with a tyne behind the wheels to at least 10-15 cm depth.

- Ripping of subsoil pans should be carried out.
- Stock should be removed when the soil is too wet.
- Crop rotations that suit the soil should be used. Soils that are susceptible to compaction and structural degradation will require longer pasture and shorter crop cycles.

For further details readers are referred to the Visual Soil Assessment publications (Shephard et al, 2000), Volumes 1 and 2, Field Guide and Soil Management Guidelines for Cropping and Pastoral Grazing on Flat to Rolling Country.

Pasture Management for Surface Erosion Control

2.1 Lowland pasture management for surface erosion control

Overgrazing of pasture can be completely avoided, though there are times in any year when feed is short and grazing pressure may be high. To minimise windblow, sheetwash or rilling, the critical thing is to maintain just enough ground cover, so that if a gale or a cloudburst strikes, a high proportion of eroded soil particles are trapped in the same paddock before they have a chance to move further.

Maintaining adequate ground cover fits in with things which most farmers do anyway in the course of grazing management: rotation of stock between paddocks, and avoidance of mob-stocking or heavy set-stocking during drought, cold conditions or wet weather.

Residual ground cover can be assessed during a paddock walk to determine if ground cover is adequate to protect soil from surface erosion;

- If one or two paces out of every ten strike bare soil or mud, ground cover is still enough to protect most of the bare patches against wind and rain.
- If between two and seven, cover is insufficient to prevent wind and rainsplash from detaching soil particles, but residual grass and litter still trap most of them before they move out of a paddock.
- If more than seven, detached soil is likely to leave in dustclouds or runoff during adverse weather.

The remedy is to spell the paddock if at all possible before it reaches this stage, and temporarily destock if it does. There is an obvious cost in terms of short-term feed utilisation. On the other hand, there is also faster recovery of pasture, and greater long-term production, if paddocks can be lightly grazed when weather conditions are adverse for plant growth. Measurements on farms show that maintaining sward density:

- Traps 90% or more of windblown and water-washed soil before it leaves the paddock;
- Helps reduce pugging and compaction of wet soil
- Prevents pasture growth losses of anything from 8 to 91% the following season.

The upper levels of pasture loss may seem high but have been recorded at diverse locations (Hawkes Bay, Manawatu, Canterbury, Otago). The highest losses occur where topsoil is stripped by water or wind; and when grass is trampled into mud on waterlogged, pugged soil. In either case growth cannot recover for a year or longer, even though climatic conditions have improved meanwhile. Light set-stocking or rotational grazing with adequate spells reduce the risk.

To ensure a healthy vegetative cover that will ensure erosion is minimised the following factors, that affect pasture/farm management, need to be recognised:

2.1.1 Climate

Temperature and day length are the two main environmental factors determining rate of plant production. Generally the higher the temperature, the greater the growth growth rates and higher the pasture production (as long as soil moisture and fertility are not limiting). Examples of this can be seen in NZ with winter growth rates varying from 20-25kb dry matter/ha/day in temperate Northland to 5 kb DM/ha/day in Gore. The key is to select pasture species that are suited and adapted to the local climate and environment.

2.1.2 Pasture type and species

As a general rule where farmed animals are to be grazed the pasture ratio should be made up of approximately one third in legumes (ie red and white clover species) while the remaining two thirds in grasses (ie ryegrass, cocksfoot, timothy etc) and herbs (eg plaintain and chickory). The species will vary throughout NZ but should be selected as suitable for that particular environment. Where droughts are more frequent then one should include dryland type suitable grass/clover species which will withstand heavy grazing and periods without water. Some drought prone pasture mixes could include wheatgrass, cocksfoot, and fescue species as well as specialised lucerne pasture where suitable.

2.1.3 Soil fertility

New Zealand soils are naturally low in nutrient status, with phosphorus, nitrogen and sulphur being the most limiting macronutrients on unimproved soils. On newly developed pastures superphosphate and if necessary lime and molybdenum need to be applied to ensure the clovers are healthy and fix atmospheric nitrogen. As the soil nitrogen levels increase the grasses can establish and become more dominant thus ensuring a good effective ground cover for 12 months of the year.

The other important factor to consider is the replacement of nutrients removed by animals and lost from the soil. The soil type, stocking rate and level of nutrient reserves built up in the soil are very important factors in working out accurately the maintenance fertiliser rates. It is essential that an ongoing soil fertility monitoring programme is undertaken at regular intervals to ensure maximum pasture production (including persistence of plant species) and optimum animal performance is achieved.

2.1.4 Grazing management

From a soil conservation point of view the aim of grazing management is to ensure high pasture production as well as maintaining pasture quality which results is a complete protective cover over the soil mantel. Pasture regrowth follows the classic "S" shaped curve which has three phases where phase one is at the start after grazing with slow regrowth. If the paddock has been overgrazed (ie where less than 500kg DM/ha) then regrowth will be slow. With phase two we find the most rapid growth and phase three is a slowing down as more pasture length creates shading. Therefore if maximum pasture production was the only objective a system that kept the pasture in phase two would be best. Under rotational grazing this means grazing down to 3-5cm at each grazing and allowing them to grow back to 15-20cm before regrazing. But under a set stocking system this corresponds to setting a stocking rate so that pasture length is never below the height range of 3-6cm. However, maximum pasture production is not the sole aim in grazing management especially where we are protecting the soil from erosion. Pasture height may not be important compared to the spread of grasses and clovers (and other weeds and herbs) over the exposed surface.

Consideration of the types of grazing animals that are farmed is important because that will also determine the amount of pasture grazed and residual that should be left.

In summary the need is to vary grazing control and a stable vegetative cover is to have a sufficient number of paddocks which can only be achieved by temporary or permanent fences. This would necessitate having at least 30-35 paddocks on the farm and in the winter period mob rotational grazing (using temporary electric fences) can be used for the daily or tow day shift within a paddock.

2.1.5 Other factors

Pasture renovation

It is paramount that annual pasture renovation be carried out worked in with the farm rotation programme. As discussed elsewhere cultivation techniques may be desirable on some sites ie where there has developed a soil pan but from a soil conservation viewpoint where soil erosion is a problem and drought conditions prevail then it is strongly recommended that no tillage or direct drilling technologies be used.

Plant and animal pest control

It is imperative that ongoing maintenance programmes are carried out to control prevent or minimise any existing or new plant or animal pest.

Irrigation management

Using additional water from an irrigation system will ensure pasture species persist longer and help maintain the protective soil cover.

2.2 Hill pasture management for surface erosion control

2.2.1 Introduction

This is the practice of continuously improving hill country pasture so that the ground is protected from sheet, wind, and shallow slip erosion by a close and vigorous mixture of clovers and ryegrasses. Subdivision fencing allows the control of grazing, thus improving sward density, and recent research has developed pasture species suitable for different climatic conditions and soil types.

2.2.2 Pastoral hill country

On hill country also, depletion of ground cover cannot be completely avoided during droughts or cold, wet winters when there is not much fresh growth. But it can be reduced by the same modifications to grazing management as for lowland pasture, i.e., maintaining greater residual feed in paddocks through rotational grazing, avoidance of mob-stocking or heavy set-stocking, and destocking the worst-affected paddocks (if feasible). There is also an additional technique which makes a big difference to density of ground cover on hill country – pasture improvement.

Since the 1940s, farmers have converted some 4 million hectares of hill country from low-producing to improved pasture, by oversowing and regular fertilisation. While carried out primarily to increase production, this practice has also had the beneficial side-effect of establishing a dense sward. Field trials have shown that establishment of improved pasture on hill country:

- Reduces surface erosion by 50 to 80%, relative to levels measured in unimproved pasture:
- Reverses pasture growth losses of 40% or more, (combined effects of over-grazing, sheet erosion and fertility depletion). In combination with closer subdivision and better grazing management, this reversal has enabled increases in stock carrying capacity from 2-7 stock units a hectare up to 8-12.

2.2.3 Utilisation of feed

It is important to utilise any extra grass feed to ensure pastures do not become rank (due to low stocking rates) and dominated by Cocksfoot, Yorkshire fog and lower fertility demanding or shade tolerant grasses and pests such as porina and grass grub. This utilisation can be achieved by more strategic fencing and increasing stock numbers over the periods when surplus dry matter is produced. Furthermore, aerial oversowing and topdressing will provide a better ground cover and more growth in the winter months. Clover response can be significant early on after oversowing until the available soil nitrogen levels are raised especially by specific topdressing and or rotational grazing.

2.2.4 Fertility transfer by stock

This can be one of the limiting factors in managing hill country pastures as stock tend to concentrate their grazing on the warmer crests of hills which can be overgrazed (bared off) and subject to frost heave, sheet and wind erosion. This important transfer of fertility results in varying nutrient levels and pasture production. The key is strategic fencing of shady blocks from the sunny so they can be grazed at the appropriate times with suitable stock types.

2.2.5 Natural reseeding

Where clover establishment has been patchy seed can be spread by stock following close grazing and summer spelling to encourage good seed set. The impermeable coat of clover seed enables it to survive through the animal and germinate in the dung. Some of the drier sunny blocks can be grazed in the spring and early summer then spelled to allow seed set and natural spread which will assist in improving the pasture ground cover.

2.2.6 Hieracium management

There are two opposing views on the role of hieracium species (hawkweed) in the hill country particularly unimproved lands which may support tussock grassland associations. One view sees the plant as beneficial because they are colonising land that can no longer sustain original grassland vegetation thus reducing the amount of bare ground which may be vulnerable to accelerated erosion. The other view sees these plants as aggressive invaders that have taken over from other species, so that their control would enable more desirable plants to be re-established.

There are four main options for controlling Hieracium namely, agricultural development, using herbicides, biological methods and grazing management. Grazing management appears to be one of the most feasible current strategies for limiting the spread of this plant onto low input land. Exclosure studies in Canterbury and Otago show grazing can reduce Hieracium flower density 40-fold limiting expansion by seed.

Low intensity spring-summer grazing significantly reduced plant number and ground cover of the upright Hieracium species ie praealtum (king devil) but not the prostate species ie pilosella (mouse ear). Conversely, high intensity grazing may assist establishment.

2.3 Tussock management for surface erosion control

Note that the comments and principles made above for hill pasture management also apply for tussock country particularly where the land lies below 900m a.s.l.

2.3.1 Introduction

Grazing management in the high country has changed dramatically over the past thirty years from traditional set stocking on large blocks of land to rotational grazing of small blocks at different times of the year. Furthermore, the period of grazing and stock grazing pressures are now recommended for each site.

There is no common set of recommendations for maintenance of improved tussock grassland. Each block, or group of blocks, will be managed for a specific purpose e.g. a sunny face to provide winter grazing.

There is now a greater tendency to manage each block individually. The basic objectives for successful pasture management and optimal dry matter as well as minimising the action of, sheet and rill erosion occur are to:

- Sustain a satisfactory level of production.
- Maintain the productive pasture species.
- Ensure good ground cover is maintained all year round.
- Ensure continuity of feed supply especially at critical stages of year.
- Utilise feed effectively so overall inputs are justified.

Level of production

Apart from soil moisture which can be manipulated, nutrient supply is the major factor affecting pasture production. It is well known that, in intensively managed pastures, maximum regrowth occurs when the sward is neither grazed too short (no less than 3-5cm), nor left to grow too long (no more than 12-18cm) before regrazing. This can only be achieved by mob stocking and rotational grazing. Intensive management is more difficult on tussock grasslands due to the terrain, unpredictable climate and most growth occurs during a short season. In such an environment it is more important to provide feedbanks where and when the stock need them than to achieve overall maximum pasture growth.

Maintaining productive pasture species

For sustainability and long term success from oversowing tussock land, it is vital to ensure pasture species persist and encourage spread of the introduced species. Because of the low soil nitrogen status, clovers dominate newly oversown pastures but as soil fertility levels improve grasses become more productive. There grasses have not been introduced annuals such as brome grass, browntop and sweet vernal will compete with the clovers. The practice of spelling for natural reseeding is more rewarding for grasses than for clovers.

Ensure good ground cover

It is essential to have an effective cover over the surface to minimise any erosion impacts. The most difficult time of the year will be in the winter and late summer when soil moisture deficits occur. Selection of suitable species which may include herbs for that environment is important.

Pasture quality when required

A high legume proportion in the sward, and a high ratio of green to dead material, will ensure good pasture quality especially when stock have high feed requirements such as ewes pre and post lambing and during flushing or mating.

Effective pasture utilisation

This can only be achieved by sufficient stock numbers and subdivision fencing. The aim is for 60-70% pasture utilisation on improved areas.

As a rule of thumb a stocking rate of at least one stock unit for every tonne of dry matter that is grown is required. For example, land in the semiarid areas which is moisture limited and producing approximately 2 tonne DM/ha/yr should carry at least 2 SU/ha/yr whereas a yellow brown earth soil in the mid tussock area producing 5 tonnes would carry approximately 5 SU/ha/yr. At least thirty hill blocks are needed to operate an effective management system that includes breeding replacement stock, and wintering on saved pasture. Because of the great variations in the mountain lands in New Zealand many different grazing practices occur. The approach taken here is to provide guidelines based on altitudinal, climate and general vegetation zones.

2.3.2 Guidelines

Alpine Zones

This zone varies around New Zealand, but basically occurs higher than 1500 m above sea level. In some localities it may include reasonable vegetative cover (alpine grasses and shrubs), but commonly has bare ground, rock and screes with snow cover for considerable periods. Frost heave is very active. Includes alpine vegetation.

Management Practices

Avoid unnecessary impacts on this zone. Where grazing is acceptable it should be at very low stock rates (eg 1 stock unit per 7-10ha or more for short summer period ie2-3 months). Care needs to be taken when setting stock rates as they type of season and environmental influences can impact on this. It is recommended in good growth seasons when there is a surplus of feed on the flats and lower hills of these properties that the summer alpine lands be spelled completely from grazing. Furthermore, this zone is suite to active and passive recreation so minimal tracking and soil disturbances should take place. Resource consents and approval from the Crowns agency will be required on any pastoral lease land for any development proposals.

- Recognise the long term impact of grazing on visual landscape. Most of these areas have important vistas and any overgrazing can be clearly seen at a distance. This applies particularly if any burning is carried out or escaped tussock fires occur. It is recommended that no burning be carried out in this zone.

- Where possible destock all grazing animals and remove feral pests. This will depend on the type of country and balance of the remainder of the farm. For it to be successful requires well sited retirement fences to keep farmed animals out of. It is important to note that in some of the more rugged terrain of the Southern Alps fencing may not be possible so the best alternative may be to graze solely cattle in the valley floor complexes.

- Where practical construct retirement fences. If Crown leasehold land, consider future land use options.

2.3.3 Retirement management practice

Practice

This is the practice of fencing out an area of severely eroded high country (usually LUC VII and VIII), which is often at the top of a mountain range. In some circumstances the topography of the area may enable stock to be completely removed without the need for large lengths of retirement fences.

Furthermore, to assist in the revegetation process of the retired land all stock that were removed will require alternative grazing elsewhere i.e. offsite feed. This is usually provided from the lower altitude, more productive land i.e. which may be AOS & TD or irrigated Lucerne to carry the same or equivalent displace stock on.

History

Retirement schemes were not really advanced at all until the Soil Conservation and Rivers Control Council provided grant incentives to farmers to carry out the practice from about 1955 onwards. This ceased in 1992 when grant monies for soil conservation purposes were terminated by government.

Application

Today the works still continues on private land but are at a slower rate unless it is part of the Crown Land Tenure Review process on Pastoral

Leasehold land where the high altitude or severely eroded lands are retired and transferred to the Crown's estate to become the responsibility of DoC.

The same land use change can occur on Freehold land where severely eroding land exists and needs to be destocked to assist in the natural or man assisted revegetation programme. There may be opportunities to involve the Queen Elizabeth II Trust if there are unique areas of tussock grassland and bush within the same block.

The most important factor in any retirement block is to ensure that ongoing animals and plant pest control is carried out as well as regular fence maintenance. It is vital that proper fire management control such as firebreak tracks and watering facilities are in place in case any escaped or wild fires occur which will damage the vegetation recovery programme.

Tall Tussock Grassland Zone

This zone commonly in the 800-1500 m above sea level range is dominated by narrow leaved snow tussock (Chionochloa rigida) with sub-dominant blue tussock (Poa colensoi) and other inter-tussock species including herbs and weeds

There may be hawkweed ingression at lower altitude. Sunny faces are more depleted due to concentrated stock grazing. They are normally utilised for summer grazing in the December to early April, by dry sheep with stocking levels less than 0.2 stock units per hectare where unimproved. May include patches of native scrub and forest, particularly on the gullies and wetter sites.

- Use conservative stocking rates for the enterprise. This will depend on whether the land has been improved or not and how much sunny land compared to shady land exists. If unimproved land then stocking rates of 1 su/1.5ha-4.0ha may be acceptable (check local guidelines) whereas on improved land the rate can vary from 2 su to say 5su per ha per year on the best moist/warm country.

- Use conservative grazing approach.

- Aim for the best protective cover possible. From a soil and water conservation viewpoint this will require regular monitoring before stock are put out on a block and when to remove a mob from the block particularly in a dry summer period. Stock may need to be mustered from a block earlier than planned in a drought season to ensure an adequate ground cover is maintained into the winter. The recovery following a drought can be enhanced by applying seed and fertiliser in the autumn if required when sufficient moisture was available.

- Consider species diversity and develop only sustainable areas. This may mean very low grazing pressures on important biodiverse areas or alternatively fence them out and no grazing at all. Furthermore, areas should be developed according to the Land Use Capability classification of the land and consideration of the biodiversity values.

- Practice conservative burning policies (Refer Burning).

- Spell native blocks during good growth years. This is a valuable management tool particularly on blocks that have bare ground and may be unsuited to oversowing or further subdivision. This will help in seed set and may build up a small feed reserve.

- Use cautious approach to management of hieracium land.

- Continually monitor and check grazing loads. The fundamental principle from a soil conservation viewpoint is to ensure optimum ground cover at all times of the year. This means the blocks should be regularly monitored by eye or using various sampling/measuring techniques which will provide good data and trends on species composition, species change, amount of dry matter produced and bare ground recovery. This monitoring will provide information which will allow changes to be made at an early phase on the time and period of grazing, grazing intensities and type of stock used.

Short Tussock Grassland

This varies in altitude between 350 m – 800 m above sea level. In some locations it includes scabweed country, but the typical cover is depleted short tussock (Festuca spp) interspersed by exotic grasses and weeds. It is more typical of the South Island lower foothills and basin lands in the semi arid areas.

Some of this grassland was severely affected by rabbits and burning, but has recovered well with better fencing and stock control. Hieracium flatweed ingression is a major concern.

The supply of feed in this zone is critical to the viability of many run properties (i.e. early spring flush feed) and is often used for younger stock. The carrying capacity varies greatly depending on the seasonal rainfall and on farm development. Shady faces are vital for stock grazing in the late summer periods with average carrying capacity of 0.3-0.4 su/ha/yr.

Management Practices

- Constant management of rabbit and other animal pests as well as any major plant pest problems (including Hieracium spread invasion). The important factor here is for regular ongoing monitoring of the main animal and plant pest populations to ensure the threshold levels are not passed. Remedial plans need to be in place and ongoing control to ensure that a good ground cover is always maintained.

- Have drought strategies in place. Although droughts may be a regular occurrence on some of this country it is vital to have strategies in place to minimise the impact that lack of water and grazing animals can have on depleting the surface ground cover. Some of these matters haven been discussed previously such as deferring grazing or grazing only in the early spring with the hogget flock and spelling to enable early seed set and natural spread of seed. The use of drought tolerant species on suitable paddocks at the lower altitude is advisable but grazing management and soil fertility status needs to be regularly monitored. Furthermore, using the most suitable lucerne pasture species for the site is recommended but special management is required (eg grazing and weed control) to ensure these valuable feed reserves persist for some time. Spelling lucerne blocks or deferred grazing may be necessary to restore them after a prolonged drought or heavy grazing. The other option is to have specific fodder feedbanks established at strategic sites around the farm which may or may not be used annually.

- Develop only sustainable areas that can withstand grazing. Otherwise consider managing them as forestry block or retire from grazing stock.

- Adopt conservative stocking policies. This is important on those lands which have been eroded and lost part or all of their topsoil as well as the threat of Hieracium plant invasion. It also depends whether they have been improved and the animal pest population threat.

- Aim for maximum protective cover. Similar management considerations to the other hill country zones.

- Exclude cattle from this land during wet periods. This is to minimise pasture species damage in improved areas but also will reduce the problem of cattle pulling out whole tussock plants (esp hard and silver tussock plants) in a wet season.

- Allow annual grasses to seed at least once per three years. This has been discussed elsewhere and is important to ensure improved and unimproved pastures persist. The provision of alternative feed sources as lucerne paddocks or special fodder banks and using irrigation on the lower flats and terraces will help facilitate removing stock off tender sunny country.

- Destock this land between November-February for seeding of sunny faces and spell blocks for a full season during good growth years. (Refer to comments above).

One of the most important management tools is to continually monitor and check grazing all the grazing loads.

Fencing Management for Surface Erosion Control

3.1 Lowlands

Fencing can also assist surface erosion control, if the fencelines follow the land types based on the principles of the NZLRI Land Use Capability Classification system. The key objective is to separate lower- producing, erosion prone units, from better arable or pastoral land.

Firstly, fence out Class VI and VII land and Class III & IV Land i.e. non-arable from arable. This practice can be used to minimise sheet and rill erosion on the steeper land by establishing more persistent pasture species. Trees can also be established on this steeper land, based on an open planting regime i.e. poplars/willows, or on more vulnerable sites as a close planting regime i.e. pine or gum woodlots. Another alternative in the drier environments and sunny depleted faces, is fencing out these areas and establishing suitable "stock fodder banks" which may only be grazed once or twice a year. Suitable species will depend on locality but could include the following:

Shrub willows; Saltbush (Atriplex halimus), Dorycnium spp, Tagasaste-tree lucerne (Chamaecytisus palmensis), Tree medick (Medicago arborea), Shrubby wattles (Acacia spp), Perennial lupin (Lupinus spp) as well as nut trees i.e. Black locust (Robinia pseudoacacia), Honey locust (Gleditsia triacanthos), Carob (Ceratonia siliqua) and others such as Chestnut spp and various Oak spp.

Secondly, fence out "High Class soils" on the farm i.e. Class I & II from surrounding more erosion prone arable land. Better productive sites, without limitations of fragipan, soil compaction, poor drainage or stoniness can be intensively managed on a sustainable management programme.

Thirdly, fence out fertile alluvial floodplains and riparian zones (units with a w sub-class) from the adjoining landform. These flood-prone areas need special management such as no cultivation and preferably direct drilling for crop and pasture establishment, so as to avert sheet wash by floodwater.

3.2 Hill country & Mountain land

Fencelines for hill country can also be made on the basis on LUC classifications. Separating classes I – V from the lower versatility units should be the first priority, where these classes are present on hill country properties principles for fencing these classes are similar to lowland areas.

Ideally class VI land should be fenced separately from class VII land as this will facilitate good grazing management, which will in turn reduce surface erosion. Class VIII should always be fenced off where possible for protection.

In the high country of New Zealand, fencing is still an important management tool for sustaining the soil and farm production. Although fences differ in design they have a similar objective, namely to facilitate stock grazing so as not to deplete the sensitive high country vegetative sward.

Fencing for the control of grazing animals has been practiced since the first sheep and cattle were introduced into New Zealand from the 1840s onwards. In the high country the basic design of fences has not changed other than more specialised wires i.e. 12.5 gauge, and using tanalised posts instead of flat standards where the site allows.

3.2.1 Size of flock and stocking rate

Size of the flock and block size is important if grazing sheep. Stocking rates will determine the paddock size ie 2000 ewes need 44 ha paddocks for grazing at 45 stock units per hectare if a proper rotational grazing system is to be practised.

3.2.2 Grazing Pressure

In general, there is more risk than benefit from periodic high grazing pressure on both unimproved and improved grasslands, especially in semiarid lands. On improved grasslands in sub-humid and particularly in humid zones, periodic high intensity stocking for herbage control and active nutrient cycling is essential as long as grazing is not to ground level.

3.2.3 Paddock shape and orientation

The key factors here are the area and length of fence and animal behaviour. The need to ensure stock water is available is paramount so watercourses should not be fenced out from stock in water short areas especially if a reticulation scheme is not available.

3.2.4 Soil Conservation Factors

Fencing will be to either act as an exclosure to stock (i.e. a debris avalanche) or as an enclosure to stock (i.e. to allow different grazing pressures on different land classes) e.g. sunny from shady. The latter may also be to spell plants for seeding or to permit seedlings to establish. The enclosure fence where possible, should follow the land-capability class boundaries wherever topography and climatic constraints permit i.e. snow drifts.

3.2.5 Siting factors

- Fences should be up and down a slope where possible to minimise damage from the snow
- Where slopes must be crossed look for stable sites, glacial ridges, old terraces and changes in slope
- For mustering purposes site fences on ridge tops so they can be seen (but not on exposed ridges as snow drifting may occur, preferable in this situation to be on the lee of the slope).
- Where acceptable from a soil and water and landscape perspective, dozing the line followed with regrassing may save costs in future.
- Cross streams at gorges or narrow confined points.
- Siting of gates is important for ease of access and movement of stock i.e. rotational grazing

3.3 Specifications

It is not the intention of this manual to list all the types and specifications as the range is almost unlimited with various combinations of HT (high tensile) and MS (mild steel) can be used. Boundary fences must be stockproof and built to last a long time.

The standard fence has seven wires, heavy strainers, posts and battens (or warratahs/metal standards) with posts 125mm or more about 4m apart. In the high country on areas subject to snow, steel standards, T irons and other sturdy material should be used. On the rough terrain standards/posts should be closer together with the wire strains being a lot shorter eg 200-240 meters. If electric fencing is to be used it should be of a standard that if the power is off the fence is still stockproof (Note electric fencing is not recommended for high altitude sites particularly retirement fences).

An alternative where snow drifting is a problem, is to construct specially designed fences that collapse in total (eg the “Hurricane chain fence”) or where the wires loosen off. Nevertheless, maintenance of these snowline fences and other high country fences must be carried out on an annual basis to ensure they exclude stock from erodible areas.

Descriptions and illustrations follow for fences that are specifically to control grazing for the purpose of soil conservation.

3.3.1 Cattleproof fence

This is an existing fence (such as a summer snowline fence) upgraded to the standard of a new fence that will allow cattle to be grazed. It may involve wooden posts, metal standards and barbed wire or electric top wire. This enables cattle to be held within the block thus facilitating more even grazing of the tussock cover and reducing the need to burn.

3.3.2 Recuperative spelling fence

This is a fence erected on lower altitude country where pasture has been depleted by sheet, wind and frost heave. It is often dry sunny land that has a short growing season ie early spring flush with grass seeding later when the vegetative material dies out and exposes bare ground. Once a fence is constructed offsite feed provisions need to be planned so the stock can be completely removed from the block for a year or in the critical summer seed set time, enabling pasture recovery. Offsite feed may be from a fodder bank or irrigated pasture.

3.3.3 Erosion Control Subdivision or Conservation fence

These terms are synonymous with one another. The fences are used to separate eroded from non eroded areas, or to separate shady from sunny faces. They facilitate better grazing control, enabling eroded or sunny faces to be grazed for short periods, and stock to be moved of while pasture recovers.

3.3.4 Rabbit Proof fence

This type of fence can be made by placing rabbit netting (usually 40mm diagonal measure netting) over an existing fence, or constructing a new fence (on the property boundary or where rabbit numbers are high). It is essential to bury the bottom of the netting approx. 150mm into the ground, or if the surface is rocky then turn up on the ground and pack well down with stones to prevent rabbit burrowing. Gates should be swung close to a concrete or board sill buried in the gateway so that rabbits cannot wriggle underneath. Once erected, follow up poisoning, or using the RHD virus or other techniques such as shooting can be more effectively carried out to reduce the rabbit numbers and allow revegetation to take place.

Rabbit-proof fence. ***Photo: ORC.***

3.3.5 Retirement fence

To specifically exclude all stock grazing from severely eroding land. This can take two forms. One is at high altitude, where severely eroded land is retired and left to naturally revegetate. This usually takes many years ie 15-20 before natural seeding and ground cover starts to show. Ongoing fence maintenance and feral animal control is essential for revegetation to succeed. The other form is on low altitude country that has been eroded. Here protection forestry species (for slope stabilisation and control of sedimentation) are established after all stock have been removed.

It is essential that all matters are considered when planning a retirement fenceline. Walk all lines before hand with an accurate measuring wheel noting all dips, angles, corners, where snow may lie and drift, gateway sites and creek crossings (floodgates, netting). Draw a profile of the line to assist in costings and type of material required. From the field notes a schedule of all the materials can be made and this is useful in pricing and tendering for materials and labour.

On the operational side, fencing gear may be best bundled and dropped by a helicopter. This will negate the need to construct unsightly access tracks, which may initiate further erosion. Each drop site should be well flagged and accessible for the fencing contractors. For additional information on specifications and design contact the local Regional Council. Any retirement fencing should be designed and constructed to last as long as possible, therefore the costs will be higher than other fences due to additional tiedowns, strainers and the like, being required.

Retirement fence, showing weed control as well as bush remnant.
Photo: John Douglas, Environment BOP.

Revegetation & Reversion

Chapter

Pasture Revegetation Practices

4.1 Lowlands

Lowland pasture revegetation may take place as a pasture renewal programme, following a cropping season at a whole paddock scale, or smaller filling in 'patches' from localised erosion. Lowland pastures are generally dominated by perennial ryegrass and white clover, other species can also be expected depending on the demands placed on the pasture by management and environmental factors.

4.1.1 Guidelines for lowland pasture revegetation

(Adapted from Langer, (1990), *Pastures their ecology and management*)

Timing

When water and nutrients are non-limiting, temperature plays a dominant role in the germination of herbage plants.

Traditionally new pastures are sown in the autumn. Autumn sowing allows the seed to go into a warm but sometimes dry seedbed, but with declining temperatures. These conditions are normally satisfactory for ryegrass, but species more sensitive to cool conditions may be disadvantaged.

Spring sowing will ensure adequate moisture and rising temperature, but the onset of early drought may cause some plant mortality where irrigation is not possible.

Fertiliser

Soil tests should be undertaken before determining fertiliser rates.

Phosphorus is essential for successful pasture establishment, particularly to stimulate the growth of seedling legumes. Generally applied at 20-35 kg P/ha when sowing, for some soils such as yellow-brown loams applications as high as 45-60 kg P/ha may be necessary. Superphosphate is often used, where sowing inoculated legumes, a reverted form should be considered as the strongly acid superphosphate may damage rhizobia.

Lime should be used to bring the pH of the soil to 6.0 or above to assist in the establishment of well-nodulated legumes, it is less important for grasses as they can tolerate lower pH levels.

Sulphur deficiency is widespread in NZ soils, but is usually corrected by 22-34 kg S/ha. Generally most deficiencies are overcome when superphosphate is applied at sowing. On soils such as brown-grey earths, where sulphur deficiency is much greater than that of phosphorus, sulphur-fortified super may be used. Elemental sulphur can be used where no phosphorus is required.

Potassium is often deficient on volcanic soils, although soils from greywacke are more commonly adequate in potassium. Legumes are less competitive than grasses in extracting available potassium from soil, and a deficiency can therefore result in poor legume establishment unless it is corrected by applying KCl or potassic superphosphate.

It is uncommon to apply nitrogen fertiliser when sowing new grass. The stimulus the grass component receives from the nitrogen may cause considerable competition with the accompanying clovers.

Seedbed preparation

When undertaking conventional cultivation the aim is to achieve a fine and firm seed-bed, so that the small grass and legume seeds make good contact with moist soil particles. Seeds should not be sown more deeply than 50mm, and frequently 25mm is more appropriate for small seeds.

Other guidelines for direct drilling, minimum tillage and conventional cultivation are covered in Chapter 1.

Species

A brief description of the most predominant pasture species is given here, seeding rates and mixes are not discussed. For more details on the suitability of different species, readers are referred to Burgess and Brock (1985), The Proceedings of the NZ Grassland Association.

Perennial ryegrass, generally dominates lowland pasture mixes. Generally rapidly establishing and requires high soil fertility, can struggle when faced with drought and insect damage. Several cultivars can withstand heavy treading and continuous grazing.

Italian ryegrass, although an annual, many types do persist for several years. Noted for their rapid establishment, which can jeopardise the establishment of other species. Requires high soil fertility and shows good growth in the autumn and winter.

Cocksfoot is well adapted to moderate fertility and low soil moisture. Some cultivars show tolerance to grass grub, and once gully established to argentine stem weevil.

Tall fescue, while slow to establish, does show a wide range of adaptability. Most tall fescue show reasonably good drought resistance and little frost damage during winter. Tolerant of acid and alkaline soils, withstand poor drainage, and some cultivars show resistance to grass grub and Argentine Stem Weevil attacks.

Phalaris is slow to establish, but once established withstands hard grazing and winter pugging and may persist for many years. Does well over cool seasons, but in dry summer conditions may become semi-dormant.

White clover, a wide range of cultivars are available with varying tolerance to severe grazing and treading. Generally requires soils of medium to high fertility, with evenly distributed rainfall. About 200 kg N/ha/yr can be expected to be fixed from the atmosphere.

Red clover, is easily recognised by its taproot, which aids in its tolerance to dry conditions. Requires high fertility and shows resistance to pests and diseases.

Grazing management

The first grazing of a new pasture is important and should be done before rapidly establishing species are able to shade out the less vigorous seedlings, the first grazing would normally take place six weeks following sowing when ryegrass is about 10cm high. Grazing should be done with a high concentration of light stock for a brief period. Frequent defoliation for the first 6-9 months will help the slower establishing species, especially legumes.

4.2 Hill Country

Slip oversowing involves the application of seed and fertiliser to bare ground left after the soil and sub soil has been removed by erosion. It is a temporary repair, pending spaced planting of trees or retirement from grazing to ensure permanent stabilisation.

The treatment of slip scars by oversowing dates back to the 1940s with work by Suckling and others at Te Awa in the Pohangina Valley in the Manawatu. (Suckling 1962) It was found that a number of factors lead to the success or failure. Available moisture was critical, followed by seed mix, fertiliser application and grazing control.

The advent of aerial sowing by fix wing aircraft, (McCaskill 1973) and later helicopters, led to larger operations in Hawkes Bay, Manawatu and Wairarapa regions after major storms. The costs of doing this work were high but in many cases subsidies reduced costs to farmers. Trails in the Whangaehu Valley in the Manawatu resulted in the restoration of slip scars to half of the production from uneroded areas, 7 to 8 years after a storm event (Garrett, 1981). Similar results were obtained in post Cyclone Bola oversowing trials in Hawkes Bay. (Quilter 1993) and (Lambert 1993) Although pasture growth will take decades to recover, and possible never reach pre erosion growth, research has shown that recovery time can be shortened by 20 years with the right management. (HBRC 1999)

It was common practice during the 70s and 80s for subsidies to be made available through Catchment Boards for slip oversowing after an extreme storms. Oversowing was carried out from East Cape to the Wairarapa during this period.

The establishment of pasture on slip sites is usually very difficult because little soil remains and skeletal soils on eroded sites are subject to extremes of wetting and drying. Root development is restricted by thin or non existent soils and the plant's ability to obtain nutrients is very limited.

4.2.1 Guidelines for hill country pasture revegetation

Factors to be considered are:

Methods

Slip oversowing can be done by hand application, or for larger areas by aeroplane. A helicopter is the most efficient as many small areas can be treated at one time, especially if concentrated fertilisers are used, and the seed-fertiliser mix can be better targeted. Pelletised seed and fertiliser will aid germination and initial growth. Some farmers have placed a large mob of sheep on the area seeded for a short period to assist in bedding in the seed.

Moisture Levels

Treatment is recommended only when there is adequate soil moisture, or when there is a reasonable chance of rainfall occurring soon after the operation.

Seed Mixtures

Seed selections should include a mixture of legumes and grasses, which are tolerant of dry conditions and low fertility. Lambrechtsen (1987) recommends the mixture in Table 4.1. The clovers must be inoculated and all seed preferably pelleted.

Table 4.1 Seed mixtures

Kg per ha	Species
6-10	Ranui perennial ryegrass
4-6	Huia white clover
1-3	Mt Barker or Tallarook sub clover

Fertiliser Mixes and Rates

Fertiliser must be applied with the seed although there is some debate as to whether nitrogen needs to be applied if inoculated clovers are included in the seed mixture. Initial rates of 150 to 200kg/ha are suggested, usually superphosphate with added minerals depending on the soil requirements. Diammonial phosphate at 100 to 150 kg/ha has been used with a repeat application 6 months later.

Grazing Control

The control of grazing by farm and feral animals is considered essential for the success of oversowing of slips. This can be difficult if large areas are treated at once, or there are large paddocks. Sheep will overgraze these sites, although they may also transfer some fertility.

A 12 months grazing restriction is the minimum suggested by most trials and larger scale operations.

The oversowing of slip scars on Class VII hill country has been carried out in small trials and larger scale programmes for over 50 years. Some of this work has been highly successful and has hastened the recovery of pasture production, while other examples have had minimal effect on recovery due to other factors such as weather, overgrazing and site exposure. At the best a 50% recovery after 5 to 10 years can be expected.

4.2.2 References

SUCKLING, F.E.T. (1962)., Te Awa Soil Conservation Experimental Area, Manawatu Catchment Board and Soil Conservation and Rivers Control Board, Wellington

HAWKES BAY REGIONAL COUNCIL, Environment Topics, Repairing Slip Damage 1999

Lambrechtsen, N.C. 1987 Grasses and Legumes for soil conservation, Plant Material Handbook.

4.3 Mountain Lands

4.3.1 Introduction

Revegetation has been one of the most important erosion control methods used in the high country since the 1950s when topdressing and oversowing of bare depleted faces first started. The earlier techniques were basic but as technology improved e.g. helicopter application, using coated seeds with inoculum, and fertiliser, more suitable plant species, better ground cover has been established for longer periods.

When revegetation is carried out, alternative feed is provided to stock once they have been completely or temporarily removed from an eroded block. Offsite feed can be anywhere on the property but is normally on the lower altitude soils. Offsite feed can be pasture improvements, or supplementary feed, or an alternative fodder bank.

- The following practices can be used to revegetate eroded faces:
- Cultivation, direct drilling, minimum tillage

- Aerial Oversowing and Topdressing (AOS &TD)-pasture species
- Native plant establishment (may include hand planting)
- Forestry protection & production planting
- Dryland pasture & alternative crop production.

Historically there was a smaller range of plants to use in the 1940s and 1950s, but advanced research in plant selection, seed pelleting (with inoculum) and method of application has enabled better adapted plants for a variety of sites.

There is a multitude of research and publications highlighting various species for a particular site. The following guidelines identify key legumes, grasses, herbs and shrubs that can be safely used.

4.3.2 Guidelines for High Country Revegetation

- Follow the illustrated table for common species

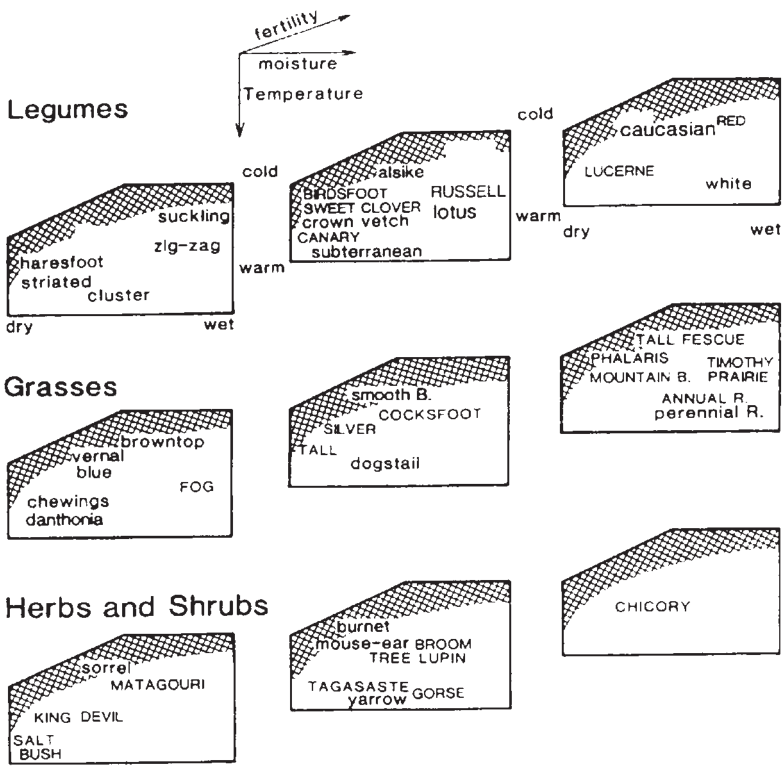


Figure 4.1 The most suitable pasture species in relation to temperature, soil moisture and levels of soil fertility.(After D. Scott and Keith Widdup, AgResearch, Lincoln)

- Legumes before grasses (select by species, and don't worry about cultivars)
- Most reasonable success is up to 800m above sea level (above this results are variable – depends on frost heave/shelter)
- Expect poor survival in harsh winters, be prepared to re-sow
- Well established species

  Legumes
  - alsike clover
  - white clover
  - red clover
  - lucerne
  - Maku lotus

  Grasses
  - cocksfoot
  - browntop/sweet vernal
  - chewings
  - timothy
  - perennial ryegrass
  - Yorkshire fog
- Species showing potential

  Legumes
  - caucasian clover
  - perennial lupin
  - birdsfoot trefoil
  - canary

  Grasses
  - tall fescue
  - tall oat
  - smooth brome
  - wheat grasses

  Herbs & shrubs
  - salt bush
  - sheeps burnet
- Others which may have a specialised role

  Legumes
  - zig-zag
  - crown vetch
  - sub clover
  - sweet clover
  - new trifoliums

  Grasses
  - red fescue
  - phalaris
  - brome

- Seeding rate varies considerably, depending on the size of seeds and environment and can range from 6 – 10kg/ha.

Fertiliser Recommendations

Yellow- brown earth (brown soils): 250 kg/ha moly super in year one and 250 kg/ha Superphosphate every 2-3 yrs then lime as practical

Yellow-grey earths(Pallic soils): 200 kg/ha moly sulphur super (28% S) for 2-3 yrs Or 150 kg/ha moly sulphur super (33%), lime as reqd.

At high altitudes more fertiliser will be required due to the greater leaching rates but the economics will need to be considered. Soil tests are vital to ensure sunny and shady faces receive their own fertiliser maintenance recipe mix. Inaccuracy of fertiliser application is not good where bare ground is being revegetated, as stock can congregate on the fertilised strips and overgraze the new plants. Use precision equipment ie helicopter with high analysis materials. Avoid waste application on non-productive sites.

Sand Dune Stabilisation Practices

5.1 Marram Planting

History

As a primary sand stabiliser, marram grass (Ammophila arenaria) has been given most prominence in the past 80 years. Although it is a plant introduced from Europe, it has proven itself as a sand dune stabiliser throughout NZ. It is also found in some inland areas: on the Volcanic Plateau and at Erewhon Park in the Rangitata Valley. Since the early 1920s, it has been planted, more recently with mechanical planters, to stabilise sand dunes because it is easy to propagate and establish. With the increasing public concern about the 'natural character' of sand dunes, other plants are gaining more prominence. They will be discussed separately. The North American Ammophila breviligulata has been tried in NZ but was found to be less effective than the European A. arenaria.

Description

Marram grass (or European beach grass) is a tall, erect, spring and summer growing perennial grass, forming compact clumps with 60-80 cm high culms. It spreads rapidly through loose sand by strong rhizomes, several metres long, which send up new shoots through accumulated sand and with new roots forming at the nodes. The leaves are bluish green, up to 6 mm wide, ribbed on the upper side and sharply pointed. They are usually tightly rolled up to minimise transpiration. The flowerheads are compact, narrow, cylindrical spike-like panicles that develop from December to January. The seedheads when ripe are green yellow but marram grass does not set much seed under New Zealand conditions. It is vegetatively propagated by splitting two-year old plants into tufts.

5.1.1 Practice

Marram grass is always propagated vegetatively by transplanting bundles of culms gathered from vigorous 2- or 3-year old clumps.

Planting material can be collected from well-established existing stands, or from special selected sheltered "nursery" areas where the marram grass production is boosted by extra fertiliser applications of nitrolime (calcium ammonium nitrate) [or equivalent] at 125 kg/ha in spring and autumn. Or it can be obtained from some commercial nurseries, often by prior arrangement.

The planting stock is dug with a sharp spade 5-10 cm below the surface. The tillers should have at least 2 nodes and are trimmed to about 50-60 cm. Some 5 to 8 culms per bundle are planted in a 20-25 cm deep V-shaped hole and well heeled in. Spacing varies from 60 x 60 cm to 100 x 100 cm depending on the degree of wind exposure. Planting is in rows at right angles to the prevailing wind (preferably on the contour) while the bundles should be staggered in the rows to prevent wind funnels. Planting time is June, July and August. Small areas and steep dunes are planted by hand, while more extensive areas are machine-planted, using specially developed marram planters pulled by a crawler tractor, or a 4-wheel drive tractor with extra wide tyres.

Nitrolime (calcium ammonium nitrate) [or equivalent] applied at 45 kg/ha in spring and autumn will increase growth and early establishment.

Marram grass is more suitable for planting on top of the foredune, and on the main dunes and blowouts further away from the coast. It has also been successfully used to stabilise inland sand dunes near Cromwell and to control blowing pumice sand along the Desert Road, north of Waiouru.

Marram grass is unpalatable to stock.

Except for topdressing, the exclusion of stock, and the speedy repair of any blow-out that may occur, no special management practices are required. Snails can be troublesome in newly planted areas and may need to be controlled.

5.1.2 Application

Where sand requires stabilisation with marram planting, the following steps should be taken first:

1 Contouring

Where possible, shape the sand dune to contours that blend in with the landscape and make the area less prone to the erosive forces of the wind. Any wind funnelling should be avoided and prevented. Where slopes are less than 15°, contouring can be done with a bulldozer, or possibly even with a tractor and blade.

Experience with repairing breaches in the foredune of major beach systems in New South Wales, Australia, following storm damage suggests that it is often more cost-effective to use heavy earthmoving machinery to reshape the beach and rebuild the foredune.

2 Temporary Retirement

The area has to be fenced beforehand to keep stock out. A standard 2-wire electric fence will keep out most cattle, so long as it is maintained and the power is kept on all the time. Since possums, hares and rabbits can still get into the area to be stabilised, they will need controlling also, unless there is good control in the adjoining areas.

3 Binding The Sand

On actively moving dunes in windswept areas, only a dense cover of marram grass will bind sand sufficiently for other plants to establish.

5.2 Spinifex planting

Spinifex sericeus (formerly known as S. hirsutus Labill.) is a native of the New Zealand and Australian coasts where it occurs naturally on the seaward side of the foredune. It diminishes towards the south of the South Island and is not found much below Dunedin. With the increasing public concern about the 'natural character' of sand dunes, this grass is gaining more prominence and it is often used in preference to marram grass. The use of Spinifex requires long-term planning and commitment.

Spinifex has been described very comprehensively in the CDVN Technical Bulletin No. 2 "Spinifex on coastal dunes – Guidelines for seed collection, propagation and establishment" by David Bergin. See especially pages 21-25 "Recommendations".

5.2.1 Description

Spinifex is a 30 cm high stoloniferous perennial grass with stout overground creeping runners (stolons), several metres long which develop roots and leafy shoots at the nodes. The leaves are silvery hairy, 7-8 cm wide, with incurved margins and a fine tapered point.

It is one of the few dioecious grasses, the male and female flowers developing on different plants in the spring. The male flowers are arranged in loose terminal or axillary clusters. The female flowers develop into large 15 cm round, spiny terminal seedheads which when ripe in mid summer break off and are blown along the beach by the wind. Volunteer seedlings are often found amongst driftwood above high water mark.

Sometimes large colonies of plants of only one sex are found; these have grown from one single seedling.

5.2.2 Practice

Spinifex can be established from seed or from cuttings made from runners. Seed germination and strike rate of cuttings is often disappointing.

Seed is best sown in January-February when the seedheads can be collected from the beach, either as complete seedheads or as individual seeds removed from the seedheads. Seed should be buried 2.5-4 cm deep. Seed sown in spring gave much better survival and growth. Soaking the seed for 24 hours in seawater will improve germination. Seed can also be collected in mid to late summer and then sown in a nursery for planting out later, which may take 9-15 months. All seed should be free of smut fungus (Ustilago spinificis), which destroys the embryo. Or seed can be collected and stored in jute or paper sacks for sowing in the next spring.

Cuttings, particularly tip cuttings, 50-60 cm long, prepared from vigorous growing stolons are planted in early spring, some 20-30 cm deep and at a spacing of 1 x 1 m. For increased effectiveness, it is better to grow the cuttings first in a nursery with bottom heat and misting, and treatment with rooting hormones and a high phosphate starter fertiliser. Then a strike rate of 80%

can be achieved, and plants will be ready for field planting in 18 months.

Spinifex can also be established by transplanting volunteer seedlings, carefully dug up without disturbing the root system, but the above nursery propagation techniques are more effective. They require long term planning and commitment.

Planting is at similar densities as those for marram: 50-60 cm in windy sites; up to 1 metre in more sheltered sites. At least 5 cm of sand should be above the potting mixture at planting. The addition of slow release fertiliser (e.g. Magamp) at about 30 g per planting hole and mixed in with the sand, assists plant establishment and vigour. Urea and other 'strong' fertilisers should be avoided.

Time of planting: spring or autumn planting gave similar results in the FRI trials, but summer planting should be avoided. Early spring planting [June to early August], well before the equinoctial gales, may be the best time because of more favourable temperature and moisture conditions.

Spinifex is less palatable than pingao, but may still be browsed by rabbits. Planted areas should be protected from disturbance by beach users through the erection of barriers and walkways; grazing animals should be excluded by fencing.

Maintenance should be by regular inspection of fences, walkways, and replanting where plants have died. Without a uniform vegetative cover, wind may dislodge sand again. Fertiliser applications on established stands at 200 kgN/ha increased cover by up to 52%. One application remained effective for 3 years.

5.2.3 Application

Spinifex is mainly used for foredune planting, especially to repair gaps in the vegetative cover on the seaward side. For example, near walkways and other high use areas, where closer planting may be desirable. Without disturbance, the extensive stolons grow down slopes and in hollows collecting sand and smoothing out the duneface.

Because of the need for nursery propagation of Spinifex for its effective establishment, the plant lends itself to community involvement, such as Beachcare or Coastcare groups. It is less readily applied to large-scale revegetation projects, unlike marram grass. The preparatory steps outlined for marram, apply here also, with possibly greater emphasis on local community involvement.

1 Contouring

Since Spinifex is more commonly used on the foredunes, it is even more important to shape the sand dune to contours that blend in with the landscape and make the area less prone to the erosive forces of the wind. Any wind funnelling should be avoided and prevented. Where slopes are less than 15°, contouring can be done with a bulldozer, or possibly even with a tractor and blade.

Experience with repairing breaches in the foredune of major beach systems in New South Wales, Australia, following storm damage suggests that it is often more cost-effective to use heavy earthmoving machinery to reshape the beach and rebuild the foredune than using manual labour.

2 Temporary Retirement

The area has to be fenced beforehand to keep people and stock out. A standard 2-wire electric fence will keep out most cattle, so long as it is maintained and the power is kept on all the time. Timber railings and timbered walkways will be necessary to control pedestrian traffic. Since possums, hares and rabbits can still get into the area to be stabilised, they will need controlling also, unless there is good control in the adjoining areas.

3 Binding The Sand

On actively moving dunes in seaward areas, only a dense cover of Spinifex, usually with pingao, will bind sand sufficiently for other plants to establish.

5.3 Pingao planting

History

Desmoschoenus spiralis (pingao) is a sedge that occurs only in New Zealand where it can be an effective sand binder on foredunes, but it is much more difficult to propagate, so that it has not considered as a major stabilisation species. It has always been valued in Maori weaving for its yellow colour. With the increasing public concern about the 'natural character' of sand dunes, this sedge is gaining more prominence and it is often used in combination with Spinifex and in preference to marram grass to stabilise foredunes and other seaward-facing situations. The use of pingao requires long-term planning and commitment.

Recent research by FRI has shown that pingao can be used as a sand stabiliser. See CDVN Technical Bulletin No. 1 "Pingao on coastal sand dunes" by D O Bergin & J W Herbert for detailed information; especially pages 18-19 "Recommendations".

5.3.1 Description

Pingao, also called golden sand sedge, is endemic in NZ, the only representative of its genus. It forms rope-like, rather woody rhizomes on foredunes; its tufts of coarse, grass-like curved leaves are 2-5 mm wide, 30-90 cm long, smooth and varying in colour from green to orange; its culms are triangular in cross-section and 30-90 cm long. The seedheads are panicles, which carry nut-like seeds that are smooth and dark brown. The seeds are arranged in a spiral pattern.

Pingao was common throughout NZ but always rare in Southland. Nowadays, there are only scattered populations of pingao, due to grazing and browsing animals, and competition with marram. It is often associated with Spinifex, which grows in similar situations.

Vigorous stands of pingao are observed where there is sand movement as on the seaward faces of foredunes. Young plants can withstand 10-20 cm of sand accumulation, whereas well-established stands can tolerate up to 70 cm of sand annually. But excessive accumulation or erosion causes dieback. Esler found on the Manawatu coast that pingao was less resistant to sand removal than other sand binders [Spinifex and marram], although its woody rhizomes may persist.

FRI studies have shown that there are distinct provenances of pingao, some with a sprawling rhizomatous habit, and others with a more tussock-like form. Others differed markedly in frost-tolerance and important differences in weaving properties were also found. It is therefore important that local material be used in revegetation plantings.

5.3.2 Practice

Pingao is best established from seedlings. Planting from rhizome cuttings is much less reliable. Seed can be collected in large quantities during December to early January, depending on summer temperatures. The seed should be shiny brown-black when collected. It should be stored in jute or paper bags, not plastic bags. The seed germinates readily with husks still attached. Seedlings should be 9-15 months old by the time they are planted in autumn or very early spring.

Time of planting: some people prefer autumn planting; others winter or early spring planting. In one trial, spring planting resulted in a much higher survival rate of pingao. At planting, the plants should be 25-30 cm tall and have at least 5 leaves. As for Spinifex, they should be planted with at least 5 cm of sand above the potting mixture; 30 g of slow-release fertiliser (e.g. Magamp) should be mixed in with the sand in the planting hole. Planting densities as for Spinifex and marram: 50-60 cm in windy sites; up to 1 m apart in more sheltered sites, and when using the rhizomatous strains.

Maintenance should be by regular inspection of fences, walkways, and replanting where plants have died. Without a uniform vegetative cover, wind may dislodge sand again. Fertiliser applications on established stands at 200 kgN/ha increased cover markedly. Since browsing by rabbits and other animals is a major cause of pingao failure, control of rabbits and hares is essential, as is the exclusion of grazing animals, such as cattle, sheep, goats and deer. The planting sites should also be protected from disturbance by beach users. Suitable barriers and walkways should be erected.

5.3.3 Application

Just like Spinifex, pingao is mainly used for foredune planting, especially in clusters to simulate its natural growth patterns. Since excessive sand accumulation or erosion will retard growth or cause dieback, survival and growth of pingao can never be guaranteed. Where strong on-shore winds cause high rates of sand movement, pingao should not be used. Marram would be more suitable. While marram could be used as a "nurse plant" for pingao, there is evidence that it could out-compete pingao, particularly on exposed sites. The use of pingao should therefore be more carefully considered beforehand than that of Spinifex and marram.

Because of the need for nursery propagation of pingao for its effective establishment, the plant lends itself to community involvement, such as Beachcare or Coastcare groups. It is less readily applied to large-scale revegetation projects, unlike marram grass. The preparatory steps outlined for marram, apply here also, with possibly greater emphasis on local community, including iwi involvement, if the pingao is to be used for weaving once well-established.

1 Contouring

Since pingao is more commonly used on the foredunes, it is even more important to shape the sand dune to contours that blend in with the landscape and make the area less prone to the erosive forces of the wind. Any wind funnelling should be avoided and prevented. Reshaping with machinery should be considered if manual methods are likely to be ineffective or too costly. Temporary shelter in the form of straw/hay bales and shelter cloth may be appropriate, if the likelihood of successful pingao establishment is high.

2 Temporary Retirement

The area has to be fenced beforehand to keep people and stock out. A standard 2-wire electric fence will keep out most cattle, so long as it is maintained and the power is kept on all the time. Timber railings and timbered walkways will be necessary to control pedestrian traffic. Since possums, hares and rabbits can still get into the area to be stabilised, they will need controlling also, unless there is already good control in the adjoining areas.

3 Binding The Sand

On actively moving dunes in seaward areas, only a dense cover of pingao, usually with Spinifex, will bind sand sufficiently for other plants to establish.

Note:

The CDVN Technical Bulletin No. 3 “Sand tussock on coastal dunes – Guidelines for seed collection, propagation and establishment” by David Bergin, describes the use of Sand Tussock in great detail. But since this grass “plays a minor role in sand stabilisation and foredune development”, it has been decided not to include it in these “Soil Conservation Practices”. Readers who wish to use this grass are advised to consult the Technical Bulletin.

5.4 Coastal forest and pasture planting

Stable sand dunes were covered with native shrubs and trees before the arrival of man. Few areas are left with relatively undisturbed coastal forest; many areas have been converted to a planted forest of Pinus radiata, usually with a belt of macrocarpa facing the seawinds. Increasingly, local residents want to convert coastal areas to the vegetation that once was there. To determine the composition of that vegetation requires local expertise or knowledge that should guide planting options and strategies. Long-term planning and commitment is essential for those locals who wish to embark on this path with assistance from local/regional councils and scientific advisers.

5.4.1 Description

This section will deal with a selection of native and introduced plants that are known to be tolerant to coastal conditions, and with a planting strategy that may bring success. A prerequisite is that the area to be planted has already been stabilised with the grasses/sedge described in the previous sections.

5.4.2 Practice

Once the dune has been stabilised, planting a permanent ground cover of shrubby or even tree species can be attempted. These species need to be hardy and persistent, and preferably nitrogen fixing. Yellow tree lupin (Lupinus arboreus) was commonly used but it has been affected by the fungus Colletotrichum gloeosporioides in recent years, so that it is less common today. But it appears to be coping with the blight, and its use should be reconsidered. Alternative shrubby legumes, such as tree lucerne (Chamaecytisus palmensis) and some shrubby wattles (Acacia sophorae and A. cyanophylla) are known to survive in coastal areas. The latter are currently not recommended because they spread by suckering and seeding, and can suppress other vegetation. And tree lucerne requires reasonably sheltered locations.

Whether one wishes to use these introduced legumes to enrich the sandy environment with nitrogen prior to planting shrubs or trees, is a local decision, dependent on local regulations, if any. The alternative is to use slow-release NPK fertilisers at planting, as described in the previous sections.

1 Native Species

Native species may be planted for preference, or for conservation areas, or to complement areas set aside as reserves. The following native species are wind and salt tolerant, and will eventually form a dense stand. They can form the nucleus of a coastal forest and have been ranked in order of preference.

Phormium tenax	Flax
Coprosma repens	Taupata
Pittosporum crassifolium	Karo
Pittosporum tenuifolium	Kohuhu
Griselinia littoralis	Papauma or Kapuka
Myoporum laetum	Ngaio
Metrosideros excelsa	Pohutukawa
Muehlenbeckia complexa	Pohuehue
Cortaderia fulvida / toetoe	Toetoe

Other native species are harder to establish on sand dunes, or may not be found in the particular botanical district. Advice should then be sought from the Dept of Conservation, and/or land management officers of regional councils.

2 Permanent Trees

As an alternative to the use of native species, a permanent tree cover can be planted to provide shelter, or a tree crop, or a mixture in the form of agroforestry. In general, a mixture of native and introduced species is recommended with the choice of species rather dependent on what the land manager can afford, and desires as end use of the trees.

3 Permanent Pasture

To establish and maintain permanent pasture on sandy soils can be very difficult because such soils usually have these features:

- Low natural fertility
- Inability to hold moisture
- Lack of organic matter
- Proneness to erosion

These features, together with exposure to strong, often very cold salt-laden winds, dry summer conditions, and often significant areas of steep contour, mean that special management techniques are needed to establish and maintain a pasture cover that will provide sustainable stock grazing and avert the risk of wind erosion. When pasture has been depleted, sand will start to blow again.

5.4.3 Application

1 Native Plants

The native plants, preferably obtained from local seed sources, should be hardened off one month prior to planting between May and August at 2-3 metre spacing among the grass/sedge vegetation which has effectively stilled sand movement. The earlier they are planted, the better. The addition of fertilisers such as nitrolime and magamp will help establishment and survival. Controlling weeds around the plants in their first year will also help to ensure survival until they are big enough to suppress weeds. Kikuyu grass may have to sprayed carefully with a herbicide such as "Gallant" or equivalent; it tends to smother plants otherwise.

Since native plants are quite palatable to stock, an effective permanent fence is a must.

2 Permanent Trees

Shelterbelts

For successful plantings, a permanent fence is a pre-requisite. The area should be about 7 metres wide for best results with an appropriate mixture of plants, at right angles to the prevailing wind. The narrower the area, the less effective the shelter, and the more likely that stock, especially cattle and horses, will reach over the fence and damage the plants.

During May to August, plant a sequence of flax (Phormium tenax), pohutukawa (Metrosideros excelsa), taupata (Coprosma repens) or ngaio (Myoporum laetum), and macrocarpa (Cupressus macrocarpa), with flax facing the sea winds.

Woodlots

The hardier timber species, used for farm forestry, can also be considered in coastal areas when they are salt wind tolerant:

Pinus radiata	Radiata pine
Pinus pinaster	Maritime pine
Pinus muricata	Bishop pine
Pinus nigra	Corsican pine
Cupressus macrocarpa	Macrocarpa or Monterey cypress
Cupressus leylandii	Leyland cypress
Eucalyptus botryoides	Southern mahogany gum

Cypresses and pines usually achieve better growth rates and forms in a coastal environment. The growth of gums and wattles can be highly variable, depending on site conditions. Silver poplar and some shrubby willows can be used to provide shelter for more productive tree crops. Other poplar and willow species are not recommended because of poor growth form and susceptibility to salt spray. From 100-500 metres landward from the foredune or cliffs, spray burn and wind shear will stunt timber species. But beyond 500 meters, normal growth rates and forms can usually be obtained behind the shelter provided by the trees to windward.

In the autumn prior to planting, establish suitable planting sites in the existing vegetation. Do not clear that vegetation if a new phase of wind erosion is to be avoided. Plant tree seedlings at 1000 stems per hectare (3-metre spacings) between June and August.

For management, do not thin or prune trees in the zone 100-200 meters landwards from fore dune or cliff; maintain as a protective shelterbelt. Between 200 and 500 metres, a standard pruning and thinning regime can be applied to pines and cypresses. Prune up to 6 metres in successive lifts, and thin to a final stand density at 200-400 stems per hectare.

Agroforestry

At sites more than 500 metres from fore dune or cliff, agroforestry can be considered, preferably if a protective planting, or at least an adequate shelterbelt has been established in the zone from 100-500 metres. Any of the timber species recommended for woodlots can be used for agroforestry. Plant tree seedlings at 200-400 stems per hectare in June to August in sites pre-prepared during the autumn.

Sheep have to be excluded for 1-2 years; cattle for 3-4 years until the seedlings are sufficiently high to escape browsing. If this is impossible, the seedlings will have to be individually protected to establish the agroforestry block that will provide highly desirable shelter for stock.

While standard pruning and thinning procedures can be followed, the risk of creating ‘top heavy’ trees should be watched carefully in this windy, coastal environment. Top heavy trees have been much more prone to breakage when thinned to 50-100 stems per hectare.

On sandy soils, the loss of pasture production as the trees get heavier crowns, is likely to be greater than that recorded on heavier soils. But the beneficial shelter effect to stock is also likely to be greater in this coastal environment with its strong, often cold sea winds.

3 Permanent Pasture

To establish pasture on sandy soils, the land should firstly be of an even contour. Shaping with bulldozer or tractor with blade to prevent wind funnelling may be required beforehand. Then a cereal, such as barley or oats, or annual lupin, which establishes quickly, should be sown as a covercrop in autumn, with the pasture species germinating more slowly under the cereals. Careful grazing will be required to maintain the covercrop, while allowing the perennial pasture species to come through.

To revegetate small areas such as blowouts, see sections on Marram, Spinifex or Pingao.

To maintain pasture on sandy soils, the key components are:

- Soil fertility
- Pasture species
- Pest control
- Grazing management
- Choice of stock

Soil fertility

Sand country is naturally low in organic matter and the major plant nutrients, NPK. The free draining nature of these sandy soils causes rapid leaching of fertiliser. While improvements in soil fertility and organic matter can be achieved over time, careful management is required to maintain them. To improve soil fertility, an appropriate fertiliser programme needs to be determined by

- Getting the soil and stock health tested to determine their current status
- Assessing nutrient losses from the farm by determining current stocking rate, stock type and management, pasture yield and management, and soil type
- Based on the above, working out fertiliser application rates for annual maintenance and improvement of soil fertility status.

Because leaching of nutrients on sand country can be high so that it is difficult to build up the nutrient status of the soil, the following practices should be considered:

- Slow release fertilisers e.g. RPR, especially on acid soils
- Organic fertilisers e.g. poultry manure to build up organic matter and moisture and nutrient retention
- Potassium applications in the spring
- Nitrogen applications to coincide with pasture growth e.g. spring and autumn
- Fertiliser applications little and often.

Pasture species

Kikuyu grass *(Pennisetum clandestinum)* is extremely common in dune regions from Waikato and Bay of Plenty northwards, but may be found in dunes further south. While it is frost-tender, it did persist for 2 winters at Lincoln. As a pasture grass, it needs heavy grazing in late spring-early summer to maintain palatability. On sand country, it can die off in severe summer droughts and become a fire hazard, or it can lead to gaps in the sward that can then lead to blowouts. If not grazed hard, it can be very competitive with existing vegetation, and seedlings of native shrubs and trees have very little chance of establishment among kikuyu (Edgar & Connor 2000, p. 575). On the other hand, its mat-forming growth habit makes it a suitable species for erosion control. Where kikuyu dominates pastures, efforts can be made to introduce and maintain temperate grasses to obtain better autumn and winter production. The following pasture plants can complement kikuyu:

Temperate grasses	
Perennial ryegrass varieties	*Lolium perenne*
Annual ryegrass varieties	*Lolium multiflorum*
Cocksfoot	*Dactylis glomerata*
Prairie grass	*Bromus willdenowii (B. unioloides)*
Yorkshire fog	*Holcus lanatus*
Tall fescue	*Festuca arundinacea*
Phalaris	*Phalaris tuberosa*
Legumes	
White clover	*Trifolium repens*
Red clover	*Trifolium pratense*
Lucerne	*Medicago sativa*
Subterranean clover	*Trifolium subterraneum*
Birdsfoot trefoil	*Lotus corniculatus*
Herbs	
Plantain	*Plantago major or P. lanceolata*
Chicory	*Cichorium intybus*

These species are best introduced by undersowing into a kikuyu sward that has been suppressed by heavy grazing, harrowing or spraying. In the absence of a kikuyu sward, these species can be undersown into a covercrop such as barley or oats, or annual lupins.

Pest control

Not only do pests such as hares, rabbits and possums have to be controlled in dune country if pasture is to establish and persist, but also slugs and snails, and various insect pests, such as grass grub, black beetle, black field cricket, and clover flea have to be controlled. Plant pests, such as thistles and ragwort can establish in pastures, opened up by insect damage.

Grazing management

Because of the difficult and changeable conditions prevailing in coastal sand country, grazing management has to be careful and flexible to cope with these conditions that can lead to surpluses and severe deficiencies in food availability. A rotational grazing system should be designed around:

- Adequate subdivision
- Adequate stock water and shelter

- Deferred grazing and spelling

Any incipient sand blows should be fenced off and treated immediately with grass/sedge planting (see sections on Marram, Spinifex or Pingao).

Choice of grazing stock

The choice of stock for sand country can have a major impact on pasture persistence, or the recurrence of blowouts, and should be carefully considered. In general, cattle damage coastal pastures far more quickly than sheep, but light-weight cattle breeds with carefully controlled grazing regimes may keep such damage to acceptable levels that prevent recurrence of erosion.

Burning Management – Mountain Lands

6.1 Introduction

In the high country of New Zealand burning has been carried out for many centuries. From the 1840s it was used to open up rank tussock grassland, which was unable to be readily grazed by sheep. Without any controls, escaped fires frequently burned several hundred hectares of erosion prone land. Stock were commonly grazed back on the burnt areas, overgrazing any regrowth and camping on the sunny faces, thus accentuating frost heave, sheet, and wind erosion.

It is now recognised that burning of vegetation should only be carried out in special circumstances and not used as a regular development tool each year. Alternative options may have minimal impacts on the soil and water. Burning on large blocks is difficult to control and fraught with many risks if the wind changes.

Before deciding to burn, consider:

- The objectives for burning tussock and intertussock grasslands (land clearance, rejuvenation of native pasture or removal of unwanted shrubs or weeds);
- What conservative burning practices are appropriate given the various land types and vegetation being burnt;
- Time since the previous burn. Burnings impact on vegetation depends on the history of management (burning of snow tussock should be only carried out once every 12-15yrs. to avoid depletion of biomass)
- Post fire management. It is essential to burn when the ground is damp in the winter months and spell the site afterwards. Follow up AOS &TD where feasible on the lower altitude sites will be beneficial. Lenient grazing in the first two years following the burn, will assist regrowth. Ensure rabbits and hares are controlled on the sunny faces.
- Whether post-fire spread of ingressive weeds e.g. hieracium spp., can be controlled
- In the wetter Lakes regions where fern and scrub are a problem burning may need to be carried out in late winter followed up with AOS & TD and erection of erosion control fence(s) for ongoing grazing control.
- Have a Burning Management Plan in place for a five year period (incorporate with the Farm Plan programme).

6.2 Guidelines For Good Burning

Source: Otago Regional Council Draft Code of Practice for Vegetation Burning in Otago 2000

Safety and control (Risk Management)

- Ensure that the necessary consents or permits are obtained from the relevant agencies and be familiar with your insurance policy provisions.
- Seek advice from a meteorological service prior to burning on the expected weather conditions.
- Avoid lighting fires while a strong wind is blowing, when a strong wind is predicted, or when conditions are such that a fire is likely to spread beyond the limits of the area that is intended to be burned.
- Use experienced people to light and control a fire.
- Do not leave fires unattended.
- Be familiar with the contact phone number of the local rural fire officer for the rural fire authority.
- Ensure that a helicopter is available if it is needed.
- Where available, use a snow cap to control the area to be burned and form an effective barrier for fires.

- Make use of fire breaks where a snow cap is not present by pre-burning prior to the main burn, to prevent the spread of fire into unwanted areas.

Controlling the Nuisance Effects of Smoke

- Endeavour to burn when weather conditions are such that smoke is likely to dissipate by the following morning.
- Avoid conditions that could result in ash deposition on skifields during the ski season and other recreational uses.

Firebreaks and access tracks

Firebreak tracks which can be dual purpose for vehicle access and stock movement have been used for many years. The main objective is to act as a defined structure where a fire can be lit from or alternatively be used as a back burning barrier. The other role is to form a normal control barrier for any natural or escaped fire thus allowing men and vehicles onto the site to help control the burns.

Since about 1950 a large number of firebreak tracks were constructed using grant assistance. In the South Island emphasis was on comprehensive range and mountain land “Strategic Firebreak Access Schemes” where all properties were linked into an overall community fire control management plan. This worked well where one had the cooperation of landowners. Within properties was another matter.

Summary of Guidelines:

- Consult with the appropriate rural fire authority
- Plan the over all route proposed using local knowledge and expertise e.g. geologist if potentially unstable slopes are present. Survey the whole track and mark all strategic corners, where culverts or cutoffs should be with pegs or coloured cloth so the operators can see from a distance
- Site so there is minimal landscape disruption
- If feasible, use a hydraulic excavator in preference to a bulldozer, to minimise site disturbance
- Use only experienced operators with the appropriate horsepower machinery
- In some instances an environmental impact assessment may be advisable (check on Resource consent requirements)
- The average width of the carriageway should be 3 metres
- The grade of the track should not exceed 1:8 (i.e. 7 degrees) except where ground conditions demand eg hard rock, bluffs. Here for short distances, grade can be increased to 1:5 (i.e. 11 degrees)
- On hill formation, frequent culverts or cutoffs need to be constructed with rockwork at both the inlet and outlet to prevent erosion of water tables, downhill batters and waterways.
- Stream crossings should be constructed to a hard bottom. Alternatively they can be armoured with rockwork, rock filled or adequate sized culverts placed (i.e. able to take storm flows)
- Uphill batters should be graded back to a slope sufficient to minimise slumping and regressing.
- Revegetation of the disturbed land should be carried out as soon as practical with suitable species according to the site and altitude. A general mix could include 3kg White clover, 2kg Montgomery Red or Alsike clover, 3kg Yorkshire fog, 3kg Browntop/Fescue and 2 kg Cocksfoot plus suitable fertiliser as 100kg Sulphate of Ammonia and 300kg Molybdic superphosphate (or sulphur). Apply the dressing with a tractor mounted spinner or blower or helicopter bucket.

Fodder Bank Establishment

7.1 Introduction

This practice has been around for some time but it is only recently that special species have been planted as alternative fodder. The technique is applicable to drier environments in the high country, but may be useful anywhere in New Zealand. It involves establishing specially adapted plants that will provide a bank of additional supplementary feed on one or two small areas, once or twice a year. Fodder banks may be planted on sites subject to frost heave, sheet and wind erosion but in general are established for "offsite feed at low altitude" to enable higher altitude eroded sites to be destocked or permanently retired.

Fodder banks have become more prominent due to many successful farm trials and research plots in particular in the 1980s in Marlborough, the Hakataramea Valley and Central Otago. These provided useful data on growth form, dry matter production and the best management practices. Traditionally fodder banks have been used as a drought management strategy, but today they are considered a wise option in erosion control.

7.2 Guidelines for Fodder Bank Establishment

Because of the large number of plants available to use in fodder banks general guidelines only will be provided. More specific details should be sought Agresearch, Alexandra. The establishment of any feedbanks should be undertaken as an integral part of the management of the whole property.

The key to these new species is that they are suited to harsh sites, often dry and of low fertility. Many of the earlier species were grasses and legumes, now the trend is to use shrubs and other herbs as well.

The success of fodder banks depends on planning, in advance so all the details on the soils, fertility, moisture regime, area, type of fencing, type of grazing stock suitable, planting equipment and where to purchase large numbers of quality plants, are known.

Common species to use (list is not inclusive, many suited to drier sites).

Shrub species

Mediterranean saltbush	Atriplex halimus
Doryncium	Doryncium species
Bluebush	Kochia prostrata
Tagasaste palmensis	Chamaecytisus
Tree medick	Medicago arborea
Ceanothus	Ceanothus species
Mountain mahogany	Cerocarpus montanus
Shrubby germander	Teucrium fruticans
Shrubby wattles	Acacia species
Perennial lupin	Lupinus spp

Tree species

Poplars (various)	Populus species
Willows	Salix species (esp. Kinuyanagi)
Other tree crops	Black locust and various nut trees – site specific

Pasture species grasses

Wheatgrasses (Agropyron Species), Tall oatgrass (Arrhenatherum elatius), Cocksfoot (Dactylis glomerata), also fescue species and native grasses.

Pasture species legumes

Milkvetches	Astragalus species
Crownvetch	Coronilla varia
Birdsfoot trefoil	Lotus corniculatus
Sainfoin	Onobrychis viciifolia
Serradella	Ornithopus sativus
Lucerne	Medicago sativa
Sweet clover	Melilotus species
Clovers	Trifolium species

Herbs

Chicory	Cichorium intybus
Sheeps burnet	Sangisorba minor

On other sites where there is more moisture and possibly shading some of the more traditional grass-clover mixes can be used but they may require higher inputs of fertiliser to ensure sustained production.

Managed Reversion of Retired Land

8.1 Lowlands

Generally, the managed reversion of lowland areas take place along streambanks or wetland areas. Fencing off areas will be one of the most important factors in retirement of these areas, this is not only vital to protect plants from stock but also removes the pressure from streambanks reducing another source of erosion.

A great deal of information has already been produced about riparian management. For further details on restoration of vegetation in these areas readers are referred to the MfE publication *Managing Waterways on Farms, A guide to sustainable water and riparian management in rural New Zealand*, June 2001.

Streambank planting of native shrubs in hill country. This site was pasture 6 years before.
Photo: D Hicks.

8.2 Hill country

8.2.1 Introduction

In the early years of soil conservation, indigenous species were not favoured by catchment boards. The prevailing view was that they should not be used on farmland, either because they were too shallow-rooted to stabilise slopes, or too slow-growing to stabilise them fast, or too unprofitable a use of productive land. If a farm conservation plan provided for fencing-off standing bush remnants or reverting scrub, it was usually on a steep face or gully, viewed as having no productive value.

On the other hand, many millions of hectares of bush, scrub and tussock, reserved in the ranges and mountain lands between 1890 and 1940, were managed by the former Department of Lands or New Zealand Forest Service for the purpose of watershed protection. The view was that retaining indigenous cover in river headwaters controlled soil erosion, reduced flooding, and maintained water supply.

With growing public interest in conservation since the 1970s, the situation has changed. Many farmers now fence off remnant bush, scrub and wetland, because they perceive them as having ecological value, and as enhancing the farm landscape. It is not uncommon for landowners to fence off small areas of pasture that are difficult to farm, such as on streambanks or in gullies, and plant them up in native species.

Many farms already have patches of tree or shrub cover on land which has never been cleared, or which has reverted. In some instances such land is stable, though more often than not, it has been left uncleared – or has reverted – because of past instability. Retention and restoration of such areas is a low-cost soil conservation option. The key elements are:

- Construct a stock-proof perimeter fence
- Undertake regular control of animal pests
- Eradicate invasive weeds

8.2.2 Fencing

If stock are still grazed on adjacent land, a good fence is essential to success of restoration. Canopy trees may remain for many decades in the presence of browsing stock, but if seedlings are persistently browsed they do not survive; ultimately the stand will open up and collapse if regeneration is insufficient to replace the old trees.

What kind of fence to build, will depend on what a farmer can afford. A traditional retirement fence, with timber posts at 3 to 4 metre spacing and 6 to 8 wires with attached battens, is clearly the best king to ensure permanent stock exclusion. At a cost of some $10 a metre, it is also the least affordable.

Go for one of these where the landowner can afford it, or where financial assistance is available from a regional council or QEII Trust. Where not, go for a low-cost fence design – it may not be as good, but it will achieve satisfactory stock exclusion most of the time. Some low-cost options are:

- Electric fence with permanent posts at 3-4 metre spacings, and either two hot wires (for cattle) or four (for sheep). These cost about $3 a metre
- Light fence with timber posts or iron fencing standards at 5 to 10 metre spacings, with four wires (two electrified) for sheep or two wires (one electrified) for cattle; and adjustable tensioners on each wire. These cost about $1 to $1.50 a metre.

It is a good idea to have a gate in the fence; alternatively removable wooden rails between tow posts; so that if stock accidentally get inside, they can be easily removed.

Remember that a retirement fence can often be made more attractive to a farmer, by placing it in a position which facilitates grazing management. It may subdivide an existing paddock in two, giving a better rotation; or create a race that concentrates stock along a ridge or a slope-foot when mustering.

8.2.3 Weed control

Once stock are excluded from a patch of reverting scrub or bush, there is a risk that regrowth may be things that farmers don't want – blackberry, gorse or subtropical shrubby weeds – as well as natural regeneration. It is best to nip these in the bud, while infestations are still small. If they get away on a retired hill country face or in a gully, the infestations will become near-impossible to control without damaging the natural regeneration.

Knockdown herbicides such as glyphosate are effective on grasses and many woody weeds, but extreme care is needed when applying them close to regenerating natives. Where infestations are small, spot-spray using a funnel, spray wand or similar to direct spray away from seedling foliage. Residual herbicides such as oxydiazon are preferable as they give longer control before re-spraying. While more toxic, they are usually herb-specific i.e. cause minimal damage to the seedlings of woody species.

Alternatively clear rank grass and weeds by hand or slasher, to free seedling that are small and slow-growing, and leave as a mulch around their stems to help suppress regrowth.

Another option is to cut 0.5 metre diameter mats of permeable erosion control fabrics and place these around each seedling. Heavy cardboard or old carpet can serve the same purpose equally well.

A third way is to use plastic tree-guards, or off-cuts from dynex tree protectors. As well as keeping seedlings free from choking by grass, these give some shelter from wind. One dynex sleeve should provide 5 to 10 seedling-sized off-cuts. If more substantial artificial shelter is needed on windy sites, peg sheltercloth to windward on wooden stakes or iron fencing standards, but use heavy-duty material that will last several years.

8.2.4 Pest control

Protection of seedling from goats, deer, rabbits, hares and possums is essential for good natural regeneration. Shooting or poisoning will generally be needed once a year for effective pest control. Additional protection may be obtained by applying repellent chemicals e.g. egg-paste to seedling. Doing this is low-cost but laborious, so is an option only in small retirements.

Fenced-off retirements at least have the advantage that pests in them can be easily targeted. Depending on the type of vegetation and when different animals feed on it, it may be possible to hit them hard once a year, instead of having to spread effort. Some regional councils have charts showing what times of year possums feed on different plants, and similar information may be available for the other animal pests.

8.3 Revegetation

Where gullies or steep faces are too unstable to contemplate spaced planting of poles in pasture or close afforestation with commercial timber species, the options are either to fence, and await natural reversion; or to assist it by planting native seedlings in the rank grass. The first option is clearly preferable because it is low-cost. In wet regions like Northland, Auckland, the Waikato, Taranaki, Nelson, Westland and Southland closed-canopy scrub will cover the site within 10 to 20 years. However it will take between 20 and 30 years for a closed scrub canopy to form in seasonally dry regions (Gisborne, Hawkes Bay, Wairarapa, eastern coastline of the South Island); and longer than 30 in dry inland regions of the South Island. Where faster revegetation is desired, the second option becomes necessary.

Key elements of successful indigenous revegetation are:

- Fencing
- Choice of species
- Planting
- Post-planting maintenance
- Pest control
- Weed control

For three of these – fencing, pest control and weed control – details are the same as for restoration of bush remnants and reverting scrub. Readers are referred to the preceding discussion of these topics. The remaining three are discussed below.

8.3.1 Choice of species

What species to plant, may be decided as much by a landowner's personal preference or by ecological considerations i.e. what the original vegetation was, as by species' effectiveness for soil conservation. The QEII Trust's Revegetation Manual (Evans 1983) and DOC's Trees for Tomorrow (Simpson 1995) are standard references for ecological restoration. The Plant Materials Handbook, Volume 3 (Van Kraayenoord and Hathaway 1986) is still

Tree planting of gully system and retirement from grazing. **Photo: Wellington RC.**

a standard reference about use of native species for soil conservation. However in the years since its publication, more has become known about their suitability for this purposed in different environments. The following list gives species that various regional councils recommend for planting on hill country slopes (including gullies).

Note that it is a nationwide list. Some of the species on it are suited to a mild climate so will establish well in northern parts of the country but may fail in cold, frosty conditions farther south. Equally, some of the hardy southern species may not thrive in hot, dry northern summers. Use local knowledge – observation of what grows well naturally in a region – when selecting plants from the list. Be open to other species as well – there may be ones that, though restricted in their natural distribution, are suited to soil conservation at particular localities.

Refer to Table 8.1 on the following page.

8.3.2 Planting

Obtain seedlings from nursery stock, preferably propagated from local seed sources. These have a better chance of survival, as they have been selected from trees that are adapted to local soils climate.

Bare-rooted seedling are easiest to handle, but have to be planted soon after supply. Potted seedlings can be held for longer, but are bulky. Root-trainer seedlings can be held for a long time, and are light to shift, but do not have much foliage which lessens their chances of survival (though good results can often be obtained).

Seedlings should preferably be not shorter than 20cm and no taller than 50cm, as smaller or larger seedlings can

Table 8.1 Species for Revegetating Hill Country Slopes.

		Tolerance to: Salt	Wind	Drought	Frost	Damp	Value for: Slope stabilisation
Agathis australis	kauri	m	m	m	l	m	*
Alectryon excelsus	titoki	m	m	m	m	m	*
Aristotelia serrata	makomako	l	m	l	h	m	?
Beilschmiedia taraire	taraire	l	m	m	l	m	*
Beilschmiedia tawa	tawa	l	m	m	m	m	*
Brachyglottis repanda	rangiora	m	m	m	m	l	?
Carmichaelia spp	broom	l	l-h	m-h	h	l	@
Carpodetus serratus	putaputaweta	l	m	m	m	l	?
Cassinia spp	tauhinu	m	m	m-h	m-h	l-h	@
Coprosma lucida	karamu	m	m	m	m	h	?
Coprosma parvifolia	leafy coprosma	l	m	m	h	l	?
Coprosma propinqua	mingimingi	l	m	m	h	m	?
Coprosma repens	taupata	h	h	m	m	l	?
Coprosma robusta	karamu	m	m	m	m	m	?
Cordyline australis	cabbage tree	m	h	m	h	h	@
Coriaria spp	tutu	l	m	l-m	m	l	@
Corokia cotoneaster	korokio	m	h	m	h	l	?
Cortaderia spp.	toetoe	m	h	h	h	m	@
Corynocarpus lavig.	karaka	h	h	m	l	l	*
Cyathea spp.	tree fern	l	l	l	h	h	@
Dacrydium cupressinum	rimu	m	m	l	m	m	*
Dacrycarpus dacryoid.	kahikatea	l	m	l	m	h	*
Dodonea viscosa	akeake	h	h	h	m	l	@
Dicksonia spp.	tree fern	l	l	l	h	h	@
Entelea arborescens	whau	m	m	m	l	m	@
Fuschia excorticata	tree fuchsia	l	m	l	m	m	@
Griselinia littoralis	broadleaf	h	h	m	m	m	*
Hebe spp	hebe	l-m	m-h	l-m	m-h	l-m	?
Hoheria spp	lacebark	l	m	l-m	m	m	@
Knightia excelsa	rewarewa	l	m	m	m	l	*
Kunzia ericoides	kanuka	l	m	h	h	m	@
Leptospermum scopar.	manuka	m	m	h	h	h	@
Macropiper excelsa	kawakawa	l	l	m	l	m	?
Melicytus ramiflorus	mahoe	l	m	m	m	m	@
Metrosideros spp	rata	l-h	m-h	m-l	m	l	*
Myoporum laetum	ngaio	h	h	m	m	l	@
Nothofagus fusca	red beech	l	m	m	h	m	*
Nothofagus menziesi	silver beech	l	m	m	h	m	*
Nothofagus solandri	black beech	l	h	h	h	m	*
Nothofagus cliffort.	mountain beech	l	m	h	h	m	*
Olearia spp	leatherwood	h	m	m	h	l	@
Paratrophis banksii	towai	l	m	l	l	m	*
Phormium tenax	flax	h	h	m	m	h	@
Phyllocladus glaucus	tanekaha	m	m	m	l	m	*
Pittosporum colensoi	black mapou	l	m	m	h	m	@
Pittosporum eugenioid.	lemonwood	l	m	l	m	m	@
Pittosporum crassifol.	karo	h	h	m	m	l	@
Pittosporum ralphii	karo	h	h	m	m	l	@
Pittosporum tenuifol.	kohuhu	l	m	m	h	l	@
Plagianthus spp	ribbonwood	l-h	m-h	m	m	m-h	?
Podocarpus totara	totara	l	m	m	h	m	*
Podocarpus halli	mountain totara	l	m	h	h	m	*
Prumnopitys ferruginea	miro	l	m	m	h	m	*
Prumnopitys taxifolia	matai	l	m	h	h	m	*
Pseudopanax arboreus	five-finger	l	m	m	m	l	@
Pseudopanax lessoni	five-finger	l	m	m	m	l	@
Pseudowintera axill.	horopito	m	h	m	m	m	@
Schefflera digitata	pate	l	l	l	m	m	?
Solanum aviculare	poroporo	l	m	h	l	m	?
Sophora spp	kowhai	l	m	m	h	m	@
Weinmannia racemosa	kamahi	l	m	m	m	m	@
Vitex lucens	puriri	m	m	m	l	m	*

Abbreviations:
l = low tolerance m = moderate tolerance h = high tolerance @ = fast growth and root spread; good value for slope stabilisation
* = slower growth and/or root spread; lower value for slope stabilisation ? = limited growth and/or root spread; some value for slope stabilisation

be difficult to establish. All plants should be hardened off in the open for about one month prior to planting.

In northern regions, seedlings are best planted in May or June, so that they establish over the winter and spring months before summer drought sets in. In central and southern regions, seedlings are best planted in mid-winter or early spring, when the plants are dormant and after they have been hardened off by frost. Any species vulnerable to out-of-season frosts should be planted as late as possible, in September or October.

Grass and weeds should be sprayed or hand-weeded 2 to 4 weeks prior to planting. A 0.5 to 1m diameter spot at each planting site is usually sufficient. This gives seedlings a chance to put on a spurt of growth before the grass and weeds grow back. Where there is concern about spray side-effects or residues, use amine-based salt preparations such as glyphosate – they have low toxicity and break down fast.

Dig a planting hole that's large enough to accommodate the seedling's roots with plenty of loose earth around and underneath once back-filled. Take care that the seedling isn't too deeply buried. Seedlings should be planted with potting mix, but ensure that the potting mix is not exposed. Keep it about 2cm below ground level and cover with soil or mulch.

Direct seeding may be worth trying, as an alternative to plantation of seedlings. Australian landcare groups report good results with this technique. In New Zealand there has been little experience with species other than manuka and kanuka, which may be established by scattering seed-pods or laying brush with ripe seed-pods still attached.

Establishment can be helped by fertilising with one or two 25g magamp pellets in the planting hole. Alternatively use 25-50 grams of granulated magamp. Magamp is preferable to urea or nitrolime which can easily burn plant roots. It is better to under-fertilise than over-do it; too much fertiliser around its roots will kill a plant.

For indigenous seedling, an initial spacing of 2.5 to 3.5 metres is recommended, so that growing trees establish reasonably dense ground cover. Most native species are naturally self-thinning, but if timber production is contemplated, hand-thinning to 5-7 metres at 20-plus years may help improve growth rates. Fast canopy closure, with suppression of competing weeds or grass within 2 to 3 years, can be achieved by planting at 1 metre spacings. However this entails 10,000 seedlings a hectare, so is feasible only on small restoration sites (or projects with big budgets e.g. road earthworks).

8.3.3 Post-planting maintenance

Post-planting maintenance can be crucial for seedling survival, but may not be practical due to other demands on time. The options are:

- Only plant what can be cared for, or
- Plant at a higher density to allow for partial planting failure, and let nature take its course

It is unrealistic to expect 100% success with any tree planting, but post-planting care and attention can greatly improve their chances. When good-quality seedlings are planted and protected, 70-80% usually survive. Where animal pests are present, they are the single largest causes of tree mortality, and much higher percentages may need to be replanted.

In inland regions, blank (re-plant) gaps in August or September, because May to July may have been too early for frost-tender seedlings; or too dry on free-draining soils. In coastal districts, blank in May or June, so that seedlings have a chance to establish before drought sets in the following summer.

If planting indigenous timber trees with a view to harvest, it is a good idea to retain some documentary evidence that they are planted and not natural regrowth, so that harvest isn't precluded by existing or future forestry legislation.

If planting indigenous trees in the hope of a commercial return, pruning is advisable to improve growth form, and avoid knotty sawlogs. Most New Zealand publications on silviculture deal specifically with radiata pine, but the techniques they recommend could be applied equally well to many timber species, including natives. For high-quality clearwood, some farm foresters make a practice of annually pruning small side-growth branches on their native timber stands.

Where trees are planted close to a valley-bottom stream in hill country, they need to be clearly separated from the stream, so they they can be felled without any risk of the channel being disturbed by logging machinery, or blocked by slash. Even where there is no intent to harvest, this is a good idea, because the channel still needs to be managed so as to maintain its flood capacity. Consider planting patterns that restore the natural flow path of floodwater. Trees that fall in may block the flow path, and need to be removed. Dense plantings, or weed regrowth enclosed by plantings e.g. self-sown willows, blackberry or gorse, may also block or deflect the flow path. Any debris which has lodged in the bed may need to be removed, if it is likely to impede passage of floodwater or direct it against banks which have been planted.

8.3.4 Nurse crops

Given that many indigenous plants are slow-growing, a nurse crop of exotic shrubs may be worth considering, to provide quick ground cover and shelter. The plants on this list form an open canopy, which admits enough light for native seedlings to grow underneath, and eventually dies out when it is overtopped by the emerging natives.

Albizzia spp.	Brush wattle
Banksia spp.	Banksias
Callistemon spp.	Bottlebrush
Chamaecytisus palmensis	tree Lucerne
Lupinus arboreus	tree lupin
Tamarix chinensis	tamarisk

Tree Lucerne in particular is good fodder for native birds, and can enable natural revegetation from seeds they bring in. Shrubby acacias are excluded from the list because many species are self-seeding and can from dense thickets. Casuarinas are excluded because there is some concern about their weed potential, though one species, river she-oak (Casuarina cunninghamii) may be suitable.

8.3.5 Concluding Remarks

That indigenous plant materials can be effective slope stabilisers in hill country, has been demonstrated by numerous storm damage surveys carried out from the 1960s onwards. Closed-canopy scrub and bush – whatever its species composition – reduces mass movement and gully erosion by 90% or more, compared with adjacent land in pasture (Clough and Hicks 1993, Hicks 1995). Reverting scrub, with an as-yet open canopy and discontinuous root mass, achieves reductions of up to 50%.

It is true that there is limited scope for spaced planting of indigenous species in grazed hill country pasture, unless the seedlings are protected or the pasture lightly grazed. Close planting of indigenous timber trees on unstable hill country, while occasionally practices, remains a less attractive commercial option than fast-growing exotics. It is the third category of hill country – unstable sites with low potential for grazing or forestry – where indigenous revegetation will be increasingly used as a soil conservation measure.

8.4 Mountain lands

This is the practice of fencing out an area of severely eroded high country (usually LUC VII and VIII), which is often at the top of a mountain range. In some circumstances the topography of the area may enable stock to be completely removed without the need for large lengths of retirement fences

Furthermore, to assist in the revegetation process of the retired land all stock that were removed will require alternative grazing elsewhere i.e. offsite feed. This is usually provided from the lower altitude, more productive land i.e. which may be AOS & TD or irrigated lucerne to carry the same or equivalent displaced stock on.

Retirement schemes were not really advanced at all until the Soil Conservation & Rivers Control Council provided grant incentives to farmers to carry out the practice from about 1955 onwards. This ceased in 1992 when grant monies for soil conservation purposes were terminated by government.

Today the works still continues on private land but are at a slower rate unless it is part of the Crown Land Tenure Review process on (Pastoral Leasehold land) where the high altitude or severely eroded lands are retired and transferred to the Crowns estate to become the responsibility of the Department of Conservation.

The same land use change can occur on Freehold land where severely eroding land exists and needs to be destocked to assist in the natural or man assisted revegetation programme. There may be opportunities to involve the Queen Elizabeth II Trust if there are unique areas of tussock grassland and bush within the same block.

The most important factor in any retirement block is to ensure that ongoing animal and plant pest control is carried out as well as regular fence maintenance. It is vital that proper fire management control such as firebreak tracks and watering facilities are in place in case any escaped or wild fires occur which will damage the vegetation recovery programme.

Runoff Control & Dewatering

Runoff Control Practices – Lowland

9.1 Introduction

The practices described apply to the rural environment and are particularly applicable on arable lands. Some practices can also be used to control siltation and erosion in urban development.

Some of these practices have not been used much in New Zealand (e.g. terracing), but are suited to intensive land use on slopes of 12° and less. The earthwork control practices should be constructed in the early phases of erosion control, e.g. graded furrows, banks as they become permanent features. The other soil conservation practices can be integrated with them afterwards, i.e. conservation tillage, cultivation, soil/pasture aeration and others.

Many of the runoff control practices have been used in New Zealand from the 1950s. They were first tried on soil conservation reserves and trial sites as The Pisa Flats (Central Otago), the Adair Reserve (South Canterbury), Glenmark Catchment (North Canterbury) and the Earnscleugh Reserve site (near Alexandra). The techniques were generally successful on low terraces and dry downland sites. From the 1970s onwards these practices seemed to loose favour as farm development and grant monies were directed into pasture improvement.

9.1.1 Contour furrows

These can be simple systems constructed on a paddock either on the contour or with a slight gradient (may also be called a diversion or drainage furrow).

Contour furrows are used to detain runoff on hill slopes. They break slopes up into a number of short lengths, preventing runoff reaching velocities that could cause rilling or sheetwash. Dung, fertiliser and soil are also retained in the furrows, creating fertile, moist conditions. More useful in drier environments where mass movement erosion is not a problem.

Graded or diversion furrows are used to divert water away from problem areas, e.g., slips, gully heads, gateways, or slopes where sheet/rill erosion occurs taking the water to safe disposal sites. They are useful to irrigate sunny knobs or ridges. Such sites are also ideal outfalls, since they tend to spread water out, rather than concentrating it in one place as occurs in a gully. Graded furrows can be used to increase the effective catchment area of a pond or dam.

Graded furrows for Drainage can be an effective and inexpensive method of draining slopes over 10°, where other methods are impractical. Put in at 10 m

Graded Furrow, North Otago.
Photo: Otago Regional Council.

intervals, they may lead to a safe disposal site or grassed waterway.

9.1.2 Factors to Consider in Design

Slope

More water will be detained on flatter land than steeper land. Furrows on steeper slopes must be installed closer together because they have less water-holding capacity. Furrows can be installed effectively on slopes of up to 25%.

Climate

In areas where high intensity rainfall frequently occurs, furrows would be spread closer together.

Soil Type

Fewer contour furrows are required on free-draining soils where infiltration is rapid. In clayey soils or wet conditions, furrows should be graded to a safe disposal site.

Size of furrow

A furrow made by a grader may detain 2-3 times the amount of water detained by a furrow constructed with a single-furrow plough.

Vegetation

Crops and lucerne which may have a high percentage of bare ground and rapid runoff, require furrows to be closer together than will grassed pastures.

Access and Cultivation

Contour spacing should allow for vehicular access routes if these have been the custom – a compromise may sometimes be necessary between desirable contour spacing and actual practice. Contours should also be spaced and positioned for future cultivation.

Machinery

Furrows can be formed by a number of different machines, and their capacity is strongly influenced by the resulting cross-sectional area. When a two furrow plough is used to form the pasture furrow, they can be ploughed so that the second turf is placed on top of the first. Construction by grader type machines is the preferred method on slopes less than 15% and plough furrows on slopes over 15%. For steeper slopes, bulldozers have been used, but it is more difficult to achieve the critical grades required.

9.1.3 Practical Points and General Recommendations for Constructing Furrows

Contour furrows

- A system of contour furrows can be expected to detain 25mm of runoff.
- Pasture furrows are useful on slopes of 7° to 18°. On flatter arable areas, broad-based terraces that are no impediment to machinery are more useful.
- Generally, vertical interval between furrows is 2 – 4m, the steepest slope point. A 2m vertical interval is equivalent to 7-l0m horizontal interval on a 10°-12° slope. On 25% slopes, the interval would be 8m
- Furrows should be compacted by running the rear tractor wheel along them when returning empty to the start of the next contour line.
- Furrows should be seeded and fertilised once constructed so they quickly get a protective cover of vegetation. In lucerne, furrows are best sown in sub. clover.
- Cattle should be kept off newly furrowed paddocks furrows. May not be suitable on deer farms as deer like to wallow and damage areas of some paddocks.
- Furrows should be broken every 50m to l00m in a zig-zag fashion down the contoured slope. This prevents overtopping and scouring occurring at any one place.
- Do not construct contour furrows on land prone to slips or tunnel gully erosion, as increased infiltration can worsen the problem. Graded furrows can be constructed only above or below these areas.
- Maintenance with a shovel over the first year is required.
- Furrows become filled up with soil, dung and vegetation after 3-4 years. The decision to reconstruct these or cut new furrows depends on whether the mitigation of soil loss and runoff has been achieved.

Graded Furrows

- Normally a grade of 1:80 should not be exceeded or scouring of furrows could result.
- A quickset level or some other accurate surveying equipment should be used for graded banks and similar structures since fall may be only 1:200 or 1:400.
- Graded furrows can be spilled out on dry knobs or ridges. These are ideal disposal sites since water is spread rather than concentrated as it is in a gully. Soil moisture levels are also improved on these normally dry sites. Regular maintenance is vital.

9.2 Broad Base Terraces and Absorption Terraces

These structures are used on flatter cropping land (2° – 7°). These are commonly 9 to 12 metres wide and 300mm high and is no impediment to the passage of machinery.

On gentle slopes (2° – 5°), a small mound will detain quite a large amount of water. However, with increasing slope, the amount detained falls off quickly.

Like pasture furrows these structures break long slopes into short lengths, encouraging absorption and preventing rilling.

On slopes steeper than 5°, terraces over l00m should be graded at 1:300. Excess water is slowly led off the land without scouring to a grassed waterway. Storage behind terraces on these slopes is insufficient to cope with heavy rain. If they are not graded overtopping may occur. (Since grades are slight, it is essential to use a Quickset level, Abney level or other surveying equipment).

Machinery for Broad Base Terraces

Terraces are built up with a grader and/or a whirlwind terracer, which is a tractor drawn implement which cuts a furrow and feeds it into an auger revolving at variable speed. By changing the auger's speed, soil can be thrown a distance of up to 8m.

Limitations

Terraces are not used extensively in New Zealand, in contrast with densely populated places overseas where flat land is scarce. Orchards and vineyards have been successfully established on terraces constructed along steep slopes (20°) in the Heathcote Valley, eliminating sheet erosion under the trees, also for kiwifruit orchards in the Tauranga district.

Terracing is very expensive and requires careful stockpiling of topsoil. Surveying is vital to ensure correct gradients and safe outfalls are established. Do not use this technique where slip erosion can occur. On slopes that may be susceptible to water logging from ponded water, graded terraces are more appropriate.

Graded banks on moderately steep Bentonitic mudstone country. *Photo: Gisborne DC.*

9.3 Graded Banks

9.3.1 Description/Purpose

Graded banks are a series of earth banks/channels formed on long slopes at very slight grades, to control the surface stormwater flow and divert the runoff to stable grassed waterways. The purpose of the graded banks is to dispose of surplus overland flow so that the risk of rill or gully initiation is lessened. They also improve drainage on clay soils.

Application

Graded banks are generally smaller than diversion banks and broad-based terraces. The banks are normally constructed using a grader on slopes of 12-15°. Graded banks can be constructed on steeper slopes using a bulldozer, but the grades are more difficult to accurately control. Over the years, a range of machinery including ploughes and whirlwind terracers have been used to install graded banks.

Ideally, the grades on the banks should be as low as possible, depending on how far the water needs to be diverted. Typically, grades are between 1:80 to 1:100. However, for short distances, grades can be as steep as 1:60 as long as scour velocities are not reached. Graded banks are installed at spacings as close as 20 m apart. They need to be accurately surveyed and grassed as soon as possible after construction. The outlet for the graded banks needs to be a waterway specifically planted (grass/trees) and managed so that it can handle the volumes of runoff without eroding. Controlled waterways should ideally spread water so that it is not concentrated.

Graded banks have been successfully used in Northland to control gullying on gumland soils, and on in the Wither hills (Marlborough) for tunnel gully control by diverting surface runoff back to ridges to spread the water flow. They have also been used in the Gisborne District in conjunction with pole planting and dewatering to control earthflow and gully erosion. In this case they were constructed using bulldozers, and poles were planted on the outside of the graded bank to help stabilise the works in the medium to long term.

9.4 Interception drains

These perform the same function as diversion channels/bunds (see Runoff Control on Earthworks Section 16) for greater design detail if required.

Description/Purpose

Interception drains are site specific measures to intercept and convey runoff at non-erosive velocities away from cropping soil to a stable outlet. They are permanent drains, and should be part of an integrated system, as opposed to contour drains which are temporary.

Installation

Grade should be less than 2 % otherwise the channel will erode and need to be stabilised with rock or erosion control fabric. The outfall may need to be protected against erosion with rock, or a flume. Because of their permanent nature and the small margin for error, these channels must be surveyed to obtain an even grade. An abney level, inclinometer or similar should be appropriate for this purpose.

Earth bunds can be used to control and direct runoff. They need to be well compacted. Any excavated channel or bund wall should be grassed to prevent scouring.

No criteria are presently advocated for a diversion channel in a cropped field. If one is required, then it is suggested that design be for the 1 in 20 year (5% AEP) storm.

Limitations

Because of the interception drain's low grade and the well-aggregated soil type, sediment will often deposit. Sedimentation can quickly compromise the capacity of the drain to transport flow and cause localised damage to crops at break out points.

Sandbags used to control drain velocity.
Photo: Franklin Sustainability Project.

Care needs to be taken in their placement so that the drains can be accessed and any sediment removed. Constructing the channel on a steeper grade so that sediment is not deposited will result in the channel itself eroding and requiring erosion control. Check dams made from rock (see Earthworks Chapter 16), sand bags etc are often necessary to control channel velocity. Sandbags filled with a mixture of sand, gravel and concrete are very effective in steep sided drains. The concrete will set and hold the sandbags together (use UV resistant bags if possible). Check dams constructed in this situation will also act as sediment retention measures because velocity reduction results in sediment deposition on.

Maintenance

Interception drains need to be inspected regularly, particularly during and immediately after heavy rain, to ensure that the drain is working correctly and is not blocked. Deposited sediment needs to be removed and any necessary repairs to the drain should be undertaken. The outfall should be checked to make sure that is free from erosion. Check that machinery movement through the site hasn't damaged the channel.

9.5 Headlands

These can be significant sources of runoff due to severe soil compaction.

Description/Purpose

Headlands are used for access and machinery turning at the ends of cropped fields. They can be designed to intercept and divert runoff to permanent interception drains. They are still used in the normal manner for machinery access.

Installation

They should be constructed at no more than a 2% grade (to avoid scour). They can be sloped back to form a benched headland. Alternatively a wide shallow "V" channel can be formed between the headland and end of the rows (this latter type requires more shaping). They can also be formed within paddocks, to break up the length of long paddock runs. If constructed to a broad shallow design, machinery can be easily driven across. Ideally the headland should be grassed (and it can then be on a slightly steeper slope as a grassed surface is more resistant to erosion).

Limitations

Common problems are insufficient capacity, erosion prone outfalls, too steep (so they erode), or too shallow a grade (so they don't flow or deposition compromises their capacity). They have often been constructed so they discharge straight to an accessway and then to a road or road side water table.

They may not have been installed where needed through paddocks, because the resultant uneven ground can affect machinery operations.

Maintenance

Remove any accumulated sediment. Re-grass as required. Repair as necessary.

9.6 Contour Drains

These perform the same function as those described in Section 15.3, Runoff Control on Earthworks.

Description/Purpose

They are temporary drains used to intercept runoff across slope in a paddock and channel it to permanent interception drains.

Installation

Contour drains should be as short in length as possible and constructed at no more than a 2% grade (to avoid scour of the channel). As a rule of thumb they should be about 300 mm deep and from 20 to 80 metres apart. Drain spacing should be 20 metres apart for slopes of

Contour drains. ***Photo: Franklin Sustainability Project.***

10% or more, and can increase to 30 and then 50 metre spacing as slope gradient changes to 3-10 % and to less than 3% respectively. As a general rule, contour drains should never be more than 80 metres apart. The actual positioning should be determined by the presence (or otherwise) of an erosion proof outfall. They should be put in immediately after sowing a crop.

Limitations

Care is needed with contour drains because they concentrate site runoff. Insufficient capacity, erosion prone outfalls, and construction on too steep a grade (so they erode) or too shallow a grade (so they don't flow) are common problems. They are often too far apart, or do not discharge into a permanent drain. They are often not installed by growers where needed, because the uneven ground hinders machinery movement and spraying operations.

Maintenance

Contour drains should be inspected during periods of prolonged rainfall and as soon as possible after heavy rainfall. Any necessary repairs should be made.

9.7 Raised Accessways

Description/Purpose

Raised accessways are constructed from roads into fields, to facilitate machinery and truck entry. A raised accessway is not a runoff conveyance system, it is a measure by which runoff is diverted away from this heavily trafficked and vulnerable spot.

Installation

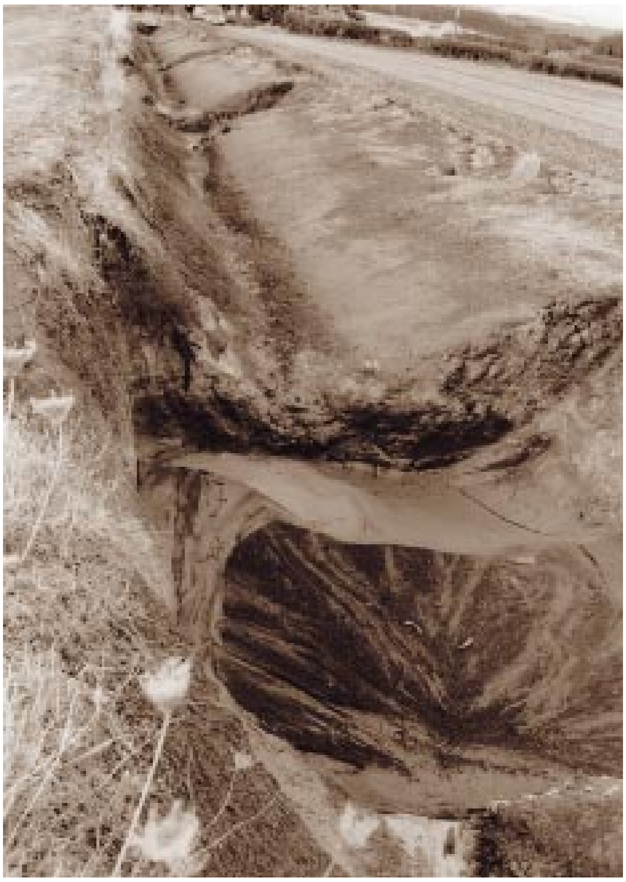
Accessways should be placed away from the lowest point in the field where water naturally flows. They should be raised above the surrounding area so runoff is diverted sideways into the nearest

Figure 2(10) raised accessway Photo –
Photo: Environment BOP.

interception drain. This can be done by placing aggregate on the accessway to mound it up, this gives all weather access and reduces the potential for future lowering of the accessway. Any accessway that goes directly onto a road will need to be piped to allow roadside drainage. The size of culvert should be checked with the local council or drainage engineer.

Maintenance:

Maintain the raised nature of the accessway to ensure runoff cannot flow directly to the road. Keep the culvert under the accessway open and clear.



Silt traps. ***Photo: Franklin Sustainability Project.***

9.8 Silt Traps

Description/Purpose

Silt traps are pits dug at intervals along interception drains. Their purpose is to retain sediment on-site and minimise off-site sedimentation.

Installation

They should be used in combination with measures that reduce runoff. The smaller the quantity of runoff directed through these measures, the less sediment they need to trap. Silt traps can be constructed either by excavating pits or constructing bunds, and passing runoff through them prior to discharge off site. Excavations can consist merely of a hole, preferably longer than it is wide and with the outlet at the opposite end to the inlet. Earth bunds can be used as well, or in conjunction with excavations, to form a silt trap.

There are currently no guidelines on trap sizing. On strongly aggregated soil types, it is probably appropriate to excavate a series of scoops along a drain rather than construct a more formal silt trap at the lower end of a paddock. However, for less well aggregated soil types, and assuming that there is an offsite need for sediment to be retained, then sediment retention ponds should be used. A drainage pipe, such as those detailed in earth bunds (see Earthworks Chapter) can be used to drain the pond or depression, or the pond should be kept shallow enough so that it is not a safety hazard. Silt traps should be located in side drains as well as permanent drains. They need to be located away from turning areas for safety reasons.

In permanent drains, small check dams constructed out of rock, timber or erosion control fabric can be used to retain sediment as well as to reduce the velocity of water in the drain. Scoops (slightly deeper excavations) at 15 – 20 metre intervals along a drain can also be used.

Limitations

Silt traps quickly fill with sediment and will need regular digging out. Minimising the quantity of runoff will reduce the frequency at which this needs to be done.

At present there is no specific design requirement for silt traps – they are merely “holes on the ground”. Room is always at a premium on grower's properties and these measures are normally "squeezed in". They may, therefore, quickly fill with sediment and lose their effectiveness during a large storm. Some recognition of catchment size, inflow velocity and silt trap capacity, undertaken at initial design, would improve their effectiveness.

The reason that they work as well as they do is because of the very strongly aggregated nature of the granular loams. This allows the particles to settle easily when runoff velocity diminishes. Silt traps will not be as effective on other soil types that readily break down to clay and silt sized particles, because their typically small capacity will not allow sufficient settling time to retain the fine particles. Sediment retention ponds (see Earthworks Chapter) would be more effective in situations where the soil is easily broken down to clay and silt.

Maintenance

Silt traps should be regularly cleaned of sediment so their effectiveness is retained. Any drainage pipe should be inspected to ensure that it is not blocked and is functional.

9.9 Subsoiling – amongst trees

Subsoiling involves the ripping of soil to a depth of about 460 to 600mm to shatter the compacted pan, particularly under tractor wheel marks, as the compacted soil obstructs water infiltration.

Application

Subsoiling can be undertaken using a D4 bulldozer with trailing twin rippers hydraulically mounted, or mounted on a hydraulic toolbar. Soil conditions need to be dry enough to shatter, but not so dry that the machine cannot rip to the required depth. Work is normally undertaken in spring/early summer (October/November) or early winter (May/June). Subsoiling runs could be up to 100 m long on slopes of less than 8°, but limited to 40 m on steeper slopes. Two rips per row are necessary to break the compacted layer under tractor tyre marks.

Subsoiling was not wholly accepted by landowners as being necessary, and their concerns related to the questionable drainage benefits as well as the possibility of killing roots of producing trees. Although the Nelson Catchment Board recommended that more investigation be undertaken to quantify the effects of subsoiling, staff had little doubt that the practice was absolutely necessary to improve the infiltration and provide a basis to initiate underground drainage patterns.

9.10 Tiled drainage beneath waterways

These include a 100 mm field tile (drainage pipe) in a trench (170 mm wide and at least 900 mm deep), and backfilled with coarse drainage metal, then grassed. The tiled grassed waterways collect water from the subsoiling and drain water via the drainage metal and field tiles safely down to the outlets. The system also provides drainage for the wetter soils of the flats and valley floors.

Main and outlet waterways usually follow natural flow paths and need little shaping to function effectively. The depth of drainage metal provides a greater capacity for drainage, and creates a break in the hard pan, allowing better infiltration to occur across the orchard. Water is able to rise as the volumes

Installation of tile drains through orchard.
Photo: Nelson Catchment Board.

Completed grassed waterway.
Photo: Nelson Catchment Board.

increase, and some surface flow may result during peak flow conditions. This surface water infiltrates into the drainage metal and tile drain as the flow decreases. Approximately 3.5 to 4 cubic metres of drainage metal is required for every 20 metres of trench.

9.10.1 Grass waterways beneath trees and along waterways

This practice includes the grassing of bare areas, particularly following subsoiling and tile draining, to stabilise the ground surface and reduce the risk of rilling and gullying.

Grassing down is normally carried out in the winter following subsoiling. The grassed waterways need to be maintained through to the outlets. This may create management problems if there is cultivation carried out on flatter land prior to the grassed waterway ending. All drainage systems need to be graded and vegetated so that they are able to convey stormwater runoff flows without scouring.

Grade line system for new orchard on rolling land.
Photo: Nelson Catchment Board.

9.11 Grade line (contour) planting

The grade line system involves planting trees along the contour on sloping land in parallel and on a similar grade to the subsoiling and tile drains. The drainage system feeds into tiled grassed waterways and then to natural channels.

Early attempts to plant orchards on the contour failed because the wide fluctuations in spacing prevented efficient spraying. Subsoil drainage allows the spacing between trees to be more uniform.

9.12 Hedges

Hedges can act as natural barriers to retain sediment. They can be effective at the bottom of a sloping paddock, between a paddock and drain, and when combined with a headland, can be used to intercept and divert runoff from up-slope. They are a permanent measure and are cheap to establish and maintain.

Hedges should be trimmed annually to encourage thick growth, particularly at ground level. Any gaps should be blocked or filled with young plants.

9.13 Contour banks

Description/Purpose

Contour mounds or banks are similar to contour furrows except they are spaced further apart and are twice the size.

Application

Contour mounds can be used in situations where the close pattern of contour furrows creates management problems such as if the area is to be cultivated frequently. Contour mounds can be constructed on similar slopes to pasture furrows, and while not as efficient as the pasture furrows, they still provide for good moisture retention, and runoff control.

9.14 Broadbased terraces

Description/Purpose

These are structures designed to detain surface runoff on flatter sites (3-12% slopes), and safely convey the runoff to a safe disposal point, normally a grassed waterway.

Application

Broadbased terraces have a large storage capacity, and usually have such a shallow batter slope that machinery and implements are able to traverse them with ease. They are normally used on relatively flat country that is intensively farmed. Broadbased terraces can be constructed with a range of earthmoving machinery. In New Zealand, a special-built machine, the “whirlwind terracer”, was trialled in the South Island at Invermay Research Station, and successfully used in the Otago region during the 1950s and 1960s.

Dewatering Techniques for Deep-seated Mass Movements

10.1 Introduction

The feasibility of stabilising mass movements varies according to the form of mass movement involved. In general, **Earthflows** occur in the weathered regolith and so are usually between 1 and 3 metres in depth. However, in deeply weathered crush zones they can be much deeper. The weathered mudstone in which they form frequently contains a high proportion of the swelling clay, montmorillonite (bentonite).

Slumps, with their semi-circular failure plane, form in deep relatively uniform cohesive materials, including unconsolidated deposits such as clays and weaker tertiary sediments. They may be ten's of metres deep at their greatest depth.

The depth of a **Slide** will frequently be determined by the depth of a particular sedimentary layer that may have lower shear strength or different hydraulic properties.

Various forms of mass movement may occur in the same failure. For example the lower part of a slide may be disrupted during failure to form an earthflow or debris flow, while the upper section may contain the rotational features of a slump.

From these definitions it can be seen that a deep earthflow is unlikely to be as large a feature as a deep slump or slide and there is therefore a greater possibility of improving the stability of an earthflow.

Deep slumps and slides are major features that are challenging even with the unrestricted use of civil engineering techniques. This is illustrated by the expense of the stabilisation works in the Cromwell Gorge. While this approach lies outside the scope of this handbook, the geotechnical principles involved apply equally well to smaller mass movements.

10.1.1 Geotechnical Principles of Slope Stabilisation

The stability of any slope is a balance between restraining forces (the shear strength of the soil) and destabilising forces (gravity). Both of these forces are affected by the angle of the slope so that the opposing forces in a gentle slope are less than those in a steep slope. Where tectonic uplift is still occurring, and streams are actively down-cutting, the slope angle will be determined by the strength of the material it is composed of. Weak material will only support a gentle slope (after its toe has been removed by stream erosion) while very strong rock will form vertical bluffs.

In effect this means that many slopes where there are high rates of uplift, including North Island East Coast tertiary sediments, are quite close to failure in their natural state. Only minor changes in the strength of the soil or to shape of the slope (e.g. the removal of the toe of the slope by stream erosion or road cutting construction) may cause failure to occur.

It is convenient to regard soil shear strength as having two components:

Cohesion is not affected by the weight of the soil overlying it and also remains relatively constant over short periods of time. It can be increased by the presence of the roots of plants and can also be reduced over time by weathering processes. In the case of weakly cemented mudstones containing swelling clays the most rapid weathering process is excessive drying. Shrinkage forces break the existing bonds and re-wetting allows swelling to occur more freely than before. In one example near Gisborne a freshly exposed hard mudstone slope became a moving earthflow in only 11 years. Vegetative cover and shade is therefore very important to preserve cohesion.

In another well documented situation, railway cuttings in Britain failed up to 80 years after their construction due to progressive failure of the slowly weakening clay material.

The **frictional** component of shear strength is dependent on the **normal** force (at right angles to the shearing force) and so greater frictional strength is mobilised deeper in the slope. Opposing this normal stress is the pressure of water in the pores of the soil (the **pore water pressure**). Consequently an increase in the pore water pressure reduces the normal force which in turn reduces the shear strength of the soil.

10.1.2 De-watering

The aim of de-watering is to manipulate pore water pressure as an effective way to increase the shear strength of the soil. The essential principle is to minimise the volume of water getting into the slope and maximise the volume leaving the slope. The means of doing this will vary with the type of mass movement being stabilised but surface drainage, sub-surface drainage, surface reshaping, and afforestation are basic tools.

Where agricultural or forestry land is at risk and some land movement can be tolerated the lower cost approaches described here can be adopted. Where assets such as buildings and roads are affected by the movement a more comprehensive engineering approach would be warranted for the higher level of protection it might provide.

10.1.3 Overview of the Site

- Obtain all available information about the movement.

- Study stereo aerial photographs to determine the boundaries of the movement as it may be greater in extent than is obvious.

- Look for similar features on the other side of the ridge and lineations across more distant slopes that may indicate a fault or crush zone. (In crush zones the underlying material has been weakened by fault action and movements, usually earthflows, are deeper and harder to control. Groundwater flow patterns may be less predictable in crush zones and fault lines and in places natural gas may be a complication.)

- Search for any available geological information to determine lithology. The dip slope and strike of strata will be significant in the case of slides.

- How deep is the movement? The height of the head scarp will give some indication but in the case of earthflows may exaggerate the actual depth.

- Locate possible infiltration zones and ponding areas which are often produced by previous movement in the upper parts of slumps and earthflows. (While ponds raise water levels in the surrounding area and presumably increase pore water pressure beneath them, it is dry hollows with substantial catchments that have the greatest impact on infiltration. Particularly in deep slumps in argillite, these hollows concentrate run-off and allowed it to flow to deeper layers through highly permeable crushed rock. As the failure plane is almost certainly of lower permeability, high pore water pressures can develop there, triggering movement.)

- Examine the toe of the slope to see if lack of support there has triggered the movement.

- How active is the movement? (Slumps and slides that have reached equilibrium may be reasonably stable, as long as their toe is not eroded or cut away. Many older farm buildings in hill country are located on the back slope of old slumps, as they may have been the only level sites not prone to flooding. Earthflows cannot be regarded as having long term stability unless extensive stabilisation work has been carried out, and they are almost certainly not suitable as building sites.)

10.1.4 Surface drainage

The rotational movement of **slump** failures can form a back-tilted zone, below the head scarp, which has poor surface drainage. Tension cracks and general deformation in this zone allows infiltrating water ready access to the shear plane. The careful use of surface ditches can drain these ponding areas and reduce infiltration. The number, location and depth of the ditches must be determined for individual sites.

Attention to detail is important to prevent scour erosion of the ditches, particularly in unconsolidated sediments where a surface cover of grass may be more important than a tree cover which leaves the soil bare. Drop structures and flumes may be needed to safely remove drainage water from the movement (those structures have been covered elsewhere in this handbook). As an alternative, willow poles can be planted where scour is a problem. The ditches need to be maintained and cleared of debris regularly to remain operative.

Where dry hollows with significant catchment areas exist, run-off should be diverted from them and out-fall ditches provided. Smoothing of the land surface to shed water may reduce infiltration and a covering of low permeability material such as a clay soil could be considered.

Any part of the slump that has very broken ground may require re-contouring by bulldozer to encourage run-off. Tension cracks should be filled and compacted to reduce infiltration.

Graded banks, very similar in appearance to small farm tracks, may be used to carry run-off to stable land off the slump or slide. The grade must be appropriate for the soil type to prevent scour, but steeper grades remove water more effectively.

Slides and earthflows may have different land forms in the upper regions but the same principles regarding infiltration reduction apply. The shear plane may be more directly exposed in the upper slide and the prevention of infiltration here is critical.

10.1.5 Sub-surface Drainage

This is intended to remove water that has already infiltrated into the soil and so also the lower pore water pressure at the shear plane. Two variations have been commonly used on farm scale works, particularly in the Gisborne-East Coast Region:

Horizontal boring, in which holes of about 50 to 60mm diameter are drilled on a gradient up into the unstable mass for distances up to 30 metres. The holes are lined with perforated pvc pipe of about 25 to 35mm diameter and the water removed is collected by a system of surface polythene pipes and disposed of safely off the movement.

Portable drilling equipment based on a small motorised posthole borer has been constructed for this purpose (see photograph) and the unit can be carried by two people in rough terrain.

Portable drilling equipment used to install horizontal bore draws. This bore produced an initial flow of approx 3,500L per hour and prevented further slope instability.
Photo: Don Miller.

The location of the boreholes is more of an art than a science as the method relies on intercepting naturally occurring high permeability zones in the movement. Experience in interpreting landscapes for signs of old tension cracks, shear planes and even fault lines is important. Some remarkably high flows have been recorded such as at a site near Tokomaru Bay in which 3000 litres per hour was removed after heavy rain by 18 bores (Hall J. 1973). Volumes of this size could not be expected from material of uniformly low permeability.

Spring taps, in which obvious springs on unstable hill slopes are excavated down to parent material to locate the source of the flow. An envelope of polythene, filter fabric and a permeable material (gravel or polystyrene beads) surrounding a length of perforated pipe is buried so as to intercept the flow and take it to the surface. From here it can be piped to safe disposal or used as a stock water supply. It is critical that the open end of the perforated pipe extends to the ground surface on the up-slope side to allow the entry of air to the system. If not, air locks will stop all flow in the pipe.

As the lower sections of an earthflow are generally too mobile for horizontal bores the most effective subsurface drainage will be in the upper sections where groundwater from higher land may be entering the earthflow. Monitoring of a number of earthflows revealed evidence of this.

The best location for spring tap and horizontal bore installations tends to be where ground water seeps to the surface in the upper section of flow. The location of these areas is best done in late

Surface recontouring of an earthflow north of Gisborne. The areas of recontoured, smoothed and cultivated land contrasts strongly with the areas of untreated earthflow. A graded bank removes water from an area of springs to stable land for safe disposal. ***Photo: Don Miller.***

summer when vegetation changes are most distinct.

Cut-off drains can be used to intercept groundwater flow, usually, but not necessarily above the unstable part of the slope. They can be particularly useful above unstable sections of farm track as they will improve both slope stability and surface wetness. Location will determined by observation of wet zones on the slope and by the presence of infiltration areas further up-slope.

In general the greater the depth, the greater the possibility of intercepting groundwater, although depth is limited by available equipment and by safety considerations. The most effective cut-off drains will penetrate to a zone of permeable material or fractured rock in which water is flowing. Unstable slopes below ash covered ridge tops could also benefit from extensive use of cut-off drains although expensive. Although untested, this could also reduce the incidence of shallow slips which are common in those circumstances.

Drains consist of a perforated pipe surrounded by a bed of permeable filter material in a back-filled trench. The choice of permeable filter surrounding the pipe is important. While not a problem in fractured hard rock, the force of the escaping water can erode the surface of softer materials and lead to clogged, ineffective drains. For example the use of gravel as a filter in non-cohesive sediments may allow migration of silts to occur. Filter fabrics should be used around the outside of the filter material, rather than directly around the pipe, to maximise flow. Details of filter design can be found in engineering text books (e.g. Cedergren, 1968).

Commercially available filter materials include vertical multi-layered composite filters to collect and remove seepage over several metres depth.

Back-fill material should prevent inflow of surface water unless a second shallow perforated pipe is included for this purpose, as the flow of surface water down to greater depths could cause instability if pipe outlets become blocked. Tree roots, particularly of willows, could block drains if trees are planted too close. If cut-off drains are reasonably straight it may be possible to clear and flush them using a high pressure pump and suitable nozzle, as with horizontal bores.

10.1.6 Surface Re-contouring

Smoothing and re-contouring is aimed at speeding run-off and eliminating hollows that could pond. Earthflows have a more disrupted and broken ground surface than slumps or slides and are generally more shallow. They move in a more regular pattern, being triggered by consistent heavy rain over a number of days. (In a Gisborne trial an average of 40mm rain per day over 10 days created approximately as much earthflow activity as Cyclone Bola did with about 400mm in 3 days)

Smoothing and re-contouring the broken surface to reduce infiltration is the most important component of de-watering an earthflow, but this may not be possible until initial surface drainage work has lowered the ground water table. In extreme cases it may take one or two years after ponding areas have been drained by ditches before the land is dry enough for bulldozer operation.

Re-contouring involves the movement of hillock material to larger hollows in the ground surface by bulldozer, to facilitate run-off of surface water. Care should be taken to preserve topsoil for later respreading. Smoothing removes the "hump and hollow" surface characteristics of earthflows. Cultivating and re-sowing pasture follows, and trials have shown that substantial growth of summer feed results, due in part to the shallow ground water table.

10.1.7 Graded Banks

Graded banks, serve to shorten the lengths of run-off overland flow paths, so decreasing the possibility of infiltration. They can also remove the outflow from spring taps and horizontal bores, where these have been installed. These banks are the most vulnerable part of the drained earthflow as water is concentrated there.

Successful earthflow de-watering projects have generally had substantial plantings of willows or poplars along the lower sides of the graded banks where their roots strengthen the soil and compensate for the increased pore water pressure under those banks. A major failure during Cyclone Bola occurred in a de-watered earthflow where the willows were less than 2 years old.