Erosion and Sediment Control Using New Zealand Native Plants – What Do We Know?

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ABSTRACT

This paper outlines what we know about the use of New Zealand's native plants for erosion and sediment control. It presents a limited review of unpublished and published information. In general terms, our detailed knowledge about what makes a native plant useful for erosion and sediment control is poor. Limited data do exist for a number of species. Most are for a few species, of a limited age range and sample number, and only collected in the last 10 years or so. This paucity of quantitative data is set in the context of a resurgence of interest in bringing more indigenous plants back into New Zealand's managed or cultural landscapes. Much of the focus of this resurgence has been to enhance indigenous biodiversity and to improve water quality in streams. Opportunities to redress our shortfall in knowledge are beginning to appear in association with development industries such as roading, mining, and construction.

Keywords
native plants, erosion, sediment control, root growth, root morphology, soil reinforcement.

1. INTRODUCTION

Since European settlement in the 1800s much of New Zealand's indigenous vegetation has been cleared for human uses such as pastoral farming, exotic forestry and urban development. The loss of ecosystem services provided by this vegetation has led to a decline in indigenous biodiversity and to the progressive degradation of waterways through increased sedimentation and nutrient pollution. The consequence has been a loss of in-stream habitat and inferior water quality in many streams and lakes throughout rural New Zealand (Phillips et al. 2001). Further, this vegetation removal created accelerated erosion in many hill country areas with concomittant losses of soil and site productivity. A need for revegetation strategies to deal with these problems began to be increasingly recognised from the 1960s.

More recently, following major floods in the Manawatu, Bay of Plenty, Coromandel, and Tauranga regions, attention has been focussed on the role of vegetation in mitigating natural hazards. In addition, the introduced willow sawfly (*Nematus oligospilus*) has caused widespread defoliation of New Zealand's willow trees since 1997, particularly in the Hawke's Bay, posing a threat to riverbank protection programmes (Charles et al. 1999). River engineers are currently seeking alternative plant species to exotic willows that provide this riverbank protection function.

Increasingly, societal considerations have also become an integral part of bringing native plants back into New Zealand's landscapes. These may include incorporating the aspirations of Māori in plant selection, for use in traditional medicine, as fibre for weaving, and for other uses. There is also now an increasing movement by grass-roots communities to undertake restoration, largely to improve biodiversity but also to improve water quality in streams and rivers (MfE 2000; Parliamentary Commissioner for the Environment 2002; NZERN – the New Zealand Ecological Restoration Network 2004 (http://www.bush.org.nz/)). Other multiple goals may include increasing New Zealand's plant diversification and maximising plant performance for carbon accrediting. New Zealand ratified the Kyoto Protocol (IPCC 2000) in 1997 (New Zealand Climate Change Office 2003), and since then the trading of carbon credits by organisations and companies at local, regional and national levels has become an integral part of the country's economy.

There is also an increasing recognition that the roading infrastructure provides a significant public asset by way of road reserves that could, and perhaps should, provide increasing conservation value. Road reserves can contain habitats and plant species that are under-represented in other reserves and can also link existing reserves and habitat islands.

This paper outlines the current state of knowledge of New Zealand's native flora for use in erosion and sediment control and makes some suggestions where future attention might be focussed.

2. EROSION AND SEDIMENT CONTROL – ROLE OF VEGETATION

How do we control erosion? Erosion and sediment control (E&SC) may be effected by mechanical or biological methods. Mechanical methods have an immediate effect and operate more or less at maximum design efficiency but are costly to construct and maintain. Biological methods such as the use of live vegetation established from seeds and cuttings are generally cheaper but their immediate effect is smaller. However, once established, vegetation provides a self-perpetuating and increasingly effective permanent control. In New Zealand, vegetation plays a major role in the stabilisation and rehabilitation of eroded lands, and in stream and river control works (van Kraayenoord & Hathaway 1986).

How does vegetation control erosion? Vegetation works in many ways; it stabilises soil by its root system, it provides a ground cover that improves microclimate and soil conditions as well as acting as a protective layer for bare soil against rain splash, it may enrich the soil by fixing nitrogen in its roots, and it may act as a filter or barrier to sediment-laden runoff (Greenway 1987; Table 1).

Table 1 How vegetation affects slope stability and erosion (modified from Greenway 1987). A – Adverse to stability, B – Beneficial to stability

	Influence
Hydrological mechanisms	
Foliage intercepts rainfall, causing absorptive and evaporative losses that reduce rainfall available for infiltration.	B
Foliage intercepts rainfall protecting the soil surface from rain splash erosion.	B
Roots and stems increase the roughness of the ground surface and the permeability of the soil, leading to increased infiltration capacity.	A
Roots extract soil moisture from the soil, which is lost to the atmosphere via transpiration, leading to lower pore-water pressures.	B
Depletion of soil moisture may accentuate desiccation cracking in the soil, resulting in higher infiltration capacity.	A
Mechanical mechanisms	
Roots reinforce the soil, increasing soil shear strength.	B
Tree roots may anchor into firm strata, providing support to the upslope soil mantle through buttressing and arching.	B
Weight of trees surcharges the slope, increasing the normal and downhill force components.	A/B
Vegetation exposed to the wind transmits dynamic forces into the slope.	A
Roots bind soil particles at the ground surface, reducing their susceptibility to erosion.	B
Low-growing vegetation may filter and trap sediment from runoff	B

Several considerations govern the choice of a particular species for erosion and sediment control (van Kraayenoord & Hathaway 1986). These include factors such as:

- Ecological considerations
- Adaptability
- Ease of propagation and availability
- Ease of establishment
- Growth habits and growth rate
- Root habit
- Soil improvement
- Resistance to mechanical damage
- Resistance to pests and diseases
- Undesirable features.

In most rehabilitation efforts, the primary purpose is to speed up the natural regenerative process or plant succession. The aim is to "fast-track" the succession by either intervening with a mix of different plant materials from different successional stages or to provide ways to promote growth, particularly in the early stages.

Some generic principles can be identified for using vegetation to rehabilitate sites whether they are for E&SC or for other reasons such as biodiversity enhancement (Simcock et al. 2005):

- Prepare a plan that specifies a rehabilitation outcome with supporting quantitative success criteria
- Minimise the area cleared and optimise the health of vegetation on adjacent areas
- Progressively strip vegetation and soils, and rehabilitate as final contours are prepared, where possible
- Shape landforms so they are stable, with rough surfaces
- Conserve and replace topsoils; minimise compaction in stockpiles and in the upper 30 cm of replaced soils
- Minimise the establishment of problem weeds
- Use plants that have the growth forms and heights that match site exposure, soil moisture, and maintenance regime
- Use organic mulches, at a minimum of 100 mm depth, not long-lived weedmat
- Maintain rehabilitated areas until a full cover of target plants has established (2–5 years).

3. WHAT WE KNOW ABOUT NATIVES FOR E&SC

3.1 INTRODUCTION

Information on the nature, and more importantly on the performance, of New Zealand's indigenous species for erosion and sediment control is generally descriptive, with much of our knowledge anecdotal. In the case of below-ground growth performance and functionality, there are few published studies on root system architecture and biomass of individual tree species (e.g., Watson et al. 1995, 1999). In addition, there is virtually no quantitative data on the role of native vegetation to filter sediment from runoff (and also very little on exotic vegetation). Nor is there information on the rates of spread of groundcover or canopy of native plants (as a surrogate for cover of bare ground).

Further, research and investigation on the use of indigenous vegetation specifically for erosion and sediment control has, in general, received little attention in New Zealand. The most significant contribution to knowledge of native plants for soil conservation (E&SC in its widest context) was in a volume of the *Plant Materials Handbook for Soil Conservation* series published in 1986 (Pollock 1986). This publication discusses the selection of suitable native plants, sources of plant materials, their propagation, field establishment and maintenance, followed by specific comment on, and the requirements of, some 70 individual species when used for soil conservation.

Up to the 1980s (and even through to today), the use of native plants in soil conservation focussed on the restoration of natural communities or impoverished remnants and the revegetation of areas near indigenous vegetation so as to prevent the onset of soil erosion. The use of native plants specifically for E&SC was largely restricted to those used in windbreaks where some species showed proven success. The lack of native plants used in E&SC relates to the fact that relatively few species were identified as able to rapidly colonise bare soil even though native vegetation has kept most of the soil in place in New Zealand over many centuries.

The introduction of exotic species that grew faster and colonised bare areas quicker became the preferred option for many revegetation projects and saw native plants relegated to those areas where there was a specific conservation or aesthetic value. Even though few native plants are suited to rapid recolonisation of severely eroded land and few can be used to protect rapidly eroding surfaces, there are quite a number that can be used to revegetate denuded but generally stable surfaces or prevent potential erosion situations from becoming active. Many of the 70 species outlined in the 1986 handbook have uses for the prevention of sheet and rill erosion, with a much smaller number recommended for mass movement or gully erosion.

Roots and the below-ground characteristics of New Zealand's native plants have also generally received little attention. Studies mostly involve one or a few specimens usually of a limited age range (e.g. Cameron 1963; Phillips & Watson 1994; Watson et al. 1995, 1999; Watson & Marden 2005; Wardle 1991; Marden et al. in press). This paucity of data is a reflection of the time-consuming nature of root system extraction, particularly for large shrubs and trees, as well as the fact that root systems are often influenced by soil conditions, making statistical comparisons difficult.

4. SPECIFIC RESEARCH AND INVESTIGATION

4.1 ROOT STUDIES

The architecture or morphology of a plant's root system and the density (or number) of plants are factors that influence the degree to which soil is reinforced. This influence is reflected in variables such as the root area ratio (Wu et al. 1979) and its' distribution in the soil. Other variables that may be reported in the literature as surrogates for "soil reinforcing effectiveness" are below-ground biomass, root depth, root spread, root:shoot ratio, and root tensile strength. In New Zealand, examination of the below-ground characteristics of native plants have been limited to only a few species, limited age ranges, limited sample numbers, and limited variables (see Table 2). Data are not reported for plants less than 1 year old. Inclusion in Table 2 is based on data or recorded observation of any of the below-ground variables in common use: root system architecture, root depth, root spread, root biomass, root:shoot ratio, root strength.

Table 2 Native species for which some below-ground information is available (modified from Phillips & Watson 1994).

Species	Species	No.	Age (y)	Reference
Kānuka	*Kunzea ericoides*	1 23	50 1–40	Watson & O'Loughlin 1985 M. Marden pers. comm. Watson et al. 1995
Mānuka	*Leptospermum scoparium*	9	13–50	Watson & O'Loughlin 1985
Beech	*Nothofagus solandri*	9–18	52	Benecke & Nordmeyer 1982
Hard beech	*Nothofagus truncata*	7	15–320	Unpubl. FRI data
Rātā	*Metrosideros umbellata*	3	?	Unpubl. FRI data
Rimu	*Dacrydium cupressinum*	26	Seedlings to poles	Cameron 1963
Tawa	*Beilschmiedia tawa*	26	Seedlings to poles	Cameron 1963
Kauri	*Agathis australis*	?	?	Bergin & Steward 2004
Tōtara	*Podocarpus totara*	?	?	Hinds & Reid (1957) reported in Bergin (2003)
Karamū	*Coprosma robusta*	45	1–5	Marden et al. in press
Ribbonwood	*Plagianthus regius*	50	1–5	Marden et al. in press
Kōwhai	*Sophora tetraptera*	44	1–5	Marden et al. in press
Lemonwood	*Pittosporum eugenioides*	50	1–5	Marden et al. in press
Kōhūhū	*Pittosporum tenuifolium*	49	1–5	Marden et al. in press
Lacebark	*Hoheria populnea*	48	1–5	Marden et al. in press
Māpou	*Myrsine australis*	50	1–5	Marden et al. in press
Fivefinger	*Pseudopanax arboreus*	46	1–5	Marden et al. in press
Rewarewa	*Knightia excelsa*	49	1–5	Marden et al. in press
Mānuka	*Leptospermum scoparium*	30	1–5	Marden et al. in press
Tutu	*Coriaria arborea*	43	1–5	Marden et al. in press
Cabbage tree	*Cordyline australis*	50 13 1 ?	1–5 1–25 ? ?	Marden et al. in press Czernin 2002; Czernin & Phillips in press Harris & Mann 1994 Simpson 2000
Flax	*Phormium tenax*	1	8	Douglas 2005
Bracken	*Pteridium esculentum*	?	?	Rowan Buxton pers. comm.
Tussocks	various	?	?	Williams 1977 McIntosh 1997 Payton & Pearce 2001
Hawkweed	*Hieracium*	?	?	John Hunt pers. comm.

In addition to those species mentioned in Table 2, a number of trees, shrubs, and herbs roots are mentioned or shown as figures or photographs in Wardle

(1991). These include *Raoulia australis*, *Melicytus alpinus*, *Lepidium sisymbrioides*, *Carmichaelia petriei*, *Chionochloa rigida*, *Festuca novae-zelandiae*, *Poa cita*, *Agrostis capillaris*, *Cassinia 'fulvida'*, *Dracophyllum acerosum*, and *Agathis australis* (kauri). Bergin & Steward (2004) document observations of kauri from earlier studies that indicate mature kauri have well-developed lateral roots that often extend beyond the width of the crown and deep "peg" roots or "sinkers" that descend from laterals, which are up to 4 m long and terminate in a network of smaller roots. These peg roots can extend to depths greater than 1.6 m (fig 3.6 in Wardle 1991).

Further to studies of the architecture and biomass of plant roots, attention has also been focussed on how strong the roots of individual plants are. The mechanical contribution of plant roots to soils is normally assessed by determining the live root-wood tensile strength or the anchorage of entire root systems. Tensile strength has been used as a measure of the amount of reinforcement that plants provide to soils (i.e. the higher the tensile strength, the better the soil reinforcement). However, more recent work indicates that this simple assumption may not hold as there are other parameters to consider (e.g. Ekanayake & Phillips 2002, 2003).

The above- and below-ground growth performance of 12 native woody species commonly found growing naturally in unstable riparian slope and/or bank environments throughout New Zealand was assessed for the first 5 years following establishment in a trial near Gisborne (Marden & Phillips 2002, 2003, 2004; Marden et al. in press) (see Table 1, Figs 1 & 2). The study aimed to provide valuable insights into the likely strengths and limitations of individual species at maturity and, therefore, into their overall potential usefulness, singly and/or as mixed plantings, for riparian stabilisation projects. This trial was the first of its kind to attempt to provide such data in New Zealand.

For all species, their root systems were typically shallow and confined to the uppermost 31 cm of soil (Fig. 1). The deepest-rooted cabbage tree reached a mean depth of ~0.4 m, while mapou had the shallowest root system at ~0.2 m. Root spread (mean maximum diameter) increased with increasing age with interspecies differences, by age 5 years, ranging from between ~1 and 2.5 m (Fig. 2). Lemonwood achieved the greatest mean root spread at ~3 m for 5-year-old plants while the very compact root systems of mapou and rewarewa barely attained a mean spread of 1 m. The root systems of individual kowhai and tutu extended to a maximum distance twice the diameter of their respective canopy widths (Marden et al. in press). At age 5 years the mean root biomass, for all species combined, was 1.2 kg/plant, and averaged ~23% of total plant biomass. Changes in the allocation of biomass for root and shoot growth appears to be species and age dependent.

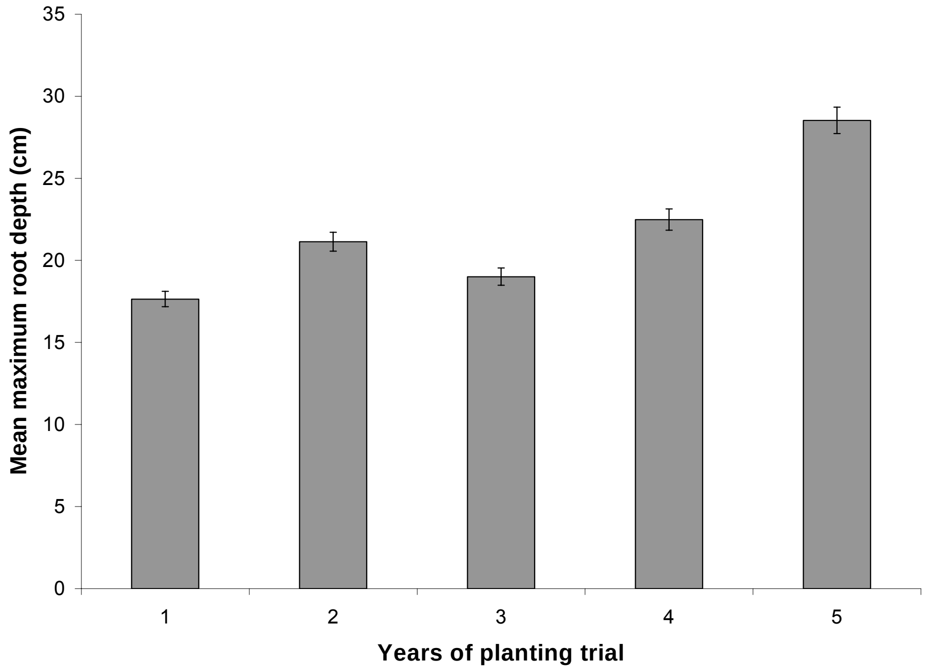

Figure 1 Mean maximum root depth for all 12 riparian species combined, over the 5-year trial period (difference between means is highly significant $F_{4,491} = 43.28$, $P < 0.001$). Error bars are ± 1 SE (from Marden et al. in press).

Figure 2 Mean maximum root spread for all 12 riparian species combined, over the 5-year trial period (difference between means is highly significant $F_{4,493} = 1584.8$, $P < 0.001$). Error bars are ± 1 SE (from Marden et al. in press).

The results of this study indicated that most trialled plants have above- and below-ground growth attributes well-suited to colonising steep and unstable riparian slopes where shallow soil failure is prevalent and/or where stream banks are rocky with skeletal soils. All form part of the early plant succession. Once established, and in the absence of grazing, they are relatively fast growing.

The study concluded that the effectiveness of riparian restoration programmes using indigenous species in general, while potentially high for low-order streams, will be limited by their relatively shallow-rooted habit for bank stabilisation on larger rivers without the prior installation of structural protection works. Treatment options that promote the quickest canopy closure and root development at all levels of the soil profile are likely to be the most effective in promoting site stability (Phillips et al. 2001).

Previous research on root depth of older-aged (13–50 years) riparian species, such as manuka, showed that the root system of mature trees penetrated to a depth of 0.5 m on stony soils and 0.8 m on sandy soils (Watson & O'Loughlin 1985). In another study, of kanuka (*Kunzia ericoides*), roots reached a maximum depth of between 1.5 and 2.2 m between 6 and 32 years old. The latter study concluded that root depth was correlated not to tree age but rather to the stoniness and depth of slope colluvium (Watson et al. 1995). In a detailed investigation of cabbage trees, the root depth of 25-year-old trees growing in alluvial gravel was estimated to be ~2 m (Czernin 2002). These studies, together with the few published reports on the root depth of some of New Zealand's tallest podocarp forest species (Cameron 1963), indicate the rooting depth for most of New Zealand's indigenous species rarely exceeded 2 m.

The conclusions from all of these root studies indicate that, in general, native species have higher tensile root strengths than exotic species, are slower growing, and have shallower root systems

4.2 MODELLING AND LARGE-SCALE ASPECTS OF VEGETATION FOR EROSION CONTROL

In addition to studies of the morphology and architecture of plant roots in New Zealand, there have also been a few studies that have attempted to advance the theoretical understanding of how vegetation contributes to slope stability via enhancing soil strength (O'Loughlin 1994; Ekanayake & Phillips 2002, 2003); how planted forests contribute to the management of regional landslide risk (Phillips et al 2000; Phillips & Marden 2005); what happens when vegetation is removed, i.e. decline in root strength/decay (Watson et al. 2000) and the role that vegetation plays in affecting specific erosion processes (O'Loughlin & Zhang 1986; Zhang et al. 1993).

4.3 MOSSES AND MINE SITE REHABILITATION

Recent research to determine the most appropriate methods for revegetating mine sites on the West Coast has been conducted by a number of mining companies together with Crown research institutes Landcare Research and Hort Research and universities such as Otago University.

In many environments mosses begin the soil formation process, increase the organic matter and act as a “nursery” for vascular plant establishment. Mosses are tolerant of naturally occurring heavy metals and low pH and have been successfully used to rehabilitate rocky steep faces such as found on mine sites. In addition, mosses are easily propagated using vegetative fragments. The use of colonising pioneer plants, such as mosses, lichens and vascular herbs, to help stabilise slopes, and revegetate disturbed land, has been shown to be successful at both Strongman and Stockton opencast mines (Craig Ross pers. comm). Hydroseeding techniques with mosses continue to be refined following these early investigations. In addition, ongoing research is aimed at determining which species are best suited to particular mine sites.

Earlier work in mine restoration focussed on preliminary examination of rooting depths of natives (Watson et al. 1998) and transplanting of whole plant-soil complexes (e.g. Langer et al. 1999) (sometimes termed salvaging or direct transfer) and. While much of the focus of the transplanting work was on rehabilitation for ecosystem/biodiversity reasons, erosion reduction was the other main reason for doing transplanting in large blocks. Creating instant cover tended to reduce the incidence of surface erosion and created a favourable environment that had a higher canopy and with larger plants. In addition, it allowed the introduction of plants that were slow to grow from seed, e.g. *Gahnia* (cutty grass) and tussock. The success of many of these salvage and transplanting operations seemed to point to the importance of soil mycorrhiza (fungi) as an important element in rehabilitation/restoration with native plants.

4.4 ROADSIDE REVEGETATION WITH NATIVES INCLUDING FERNS

Revegetation of roadsides with native plants has been going on for decades in New Zealand either by direct intervention or by natural processes of succession. However, the driver for much of the intervention has been either habitat/biodiversity enhancement, such as where roads are within national parks or similar high-value areas, or for aesthetic reasons. E&SC concerns were generally a secondary benefit to many of these earlier plantings.

In more recent years, attention has begun to be focussed equally on both E&SC and biodiversity and several trials have employed the use of “application systems” for native planting in hard sites (e.g. long-stem-tube root stock, hydroseeding with native plants, transplanting trials etc.).

Some of this more recent work has been related to setting up demonstration trials of shaping and surfacing roadside areas to reduce erosion and sedimentation and increase favourable microsites for plant and seedling growth (Robyn Simcock pers. comm) These investigations include:

- use of logs and stumps to create informal 'debris dams' on backfilled slopes (Mamuku)
- scalloping/gouging road surfaces vs shallow tining (Arthur's Pass)
- use of mulches for erosion & weed control & soil recovery; sticking mulches to slopes
- netting or coir logs with woodchip or compost fill (and potentially plants on top)

- Role of topsoil for plant growth and cover in road revegetation
    - topsoil vs no topsoil in Central North Island (and then fertiliser response of ti tree in non-topsoiled sites; value of repeat fertilisation in nutrient poor substrates)
    - topsoil vs no topsoil in revegetation areas
    - topsoil vs no topsoil Arthur's Pass (weeds and growth vs few weeds but high native biodiversity and low growth).

Plant lists of native species for planting on particular roadside sites are provided in Simcock et al. (2005)

Based on observation of natural colonisation of roadsides by ferns and their ability to be "managed" including mowing, there is now interest in exporing how ferns can be used to provide native plant cover in many areas. Initial results of trial work suggest that kiokio (*Blechnum novaezealandiae (capense)*) is a useful plant for many areas as it resists invasion by most other plants and can cope with moderate management (appendix 4 in Simcock et al. 2005).

More recently, a 2-year project to research native ferns began in 2004 with a laboratory screening programme to determine which ferns can be established quickly at harsh sites where container-grown plants wouldn't survive and seeding is likely to fail (Robert Coulson & Craig Ross pers. comm). Field trials will be carried out in autumn 2005. A layer of fern cover will help stabilise banks and, because they droop, will have the added advantage that mowing won't be needed.

> "We are dealing with spores for the first time, not seeds, and going right back to the basics of fern reproduction to learn what is the best micro-environment to get ferns established. This knowledge for hydroseeding ferns doesn't exist anywhere else in New Zealand or the world." Dr Craig Ross.

4.5 REVEGETATING COASTAL DUNES

There has been considerable effort in the last few decades focussing on the control of coastal sand dunes. There is now a national network of people with an interest in sand dune vegetation and rehabilitation. The Coastal Dune Vegetation Network (CDVN) collects and distributes information to help them preserve these fragile ecosystems. More than 200 organisations and individuals are involved in the Network, including regional and district councils, other Crown research institutes, forestry companies, tertiary education institutes, iwi, consultants, nurseries, and community groups such as Beach Care and Coast Care. This collaborative research network is administered by Ensis. Plants are used to help stabilise dunes and provide habitat for many insects, animals and birds, including migratory birds. Action is underway around the country to protect and restore coastal dune plants.

Revegetation efforts have focussed predominantly on the native plants pingao (a sedge), spinifex (a grass), and sand tussock, as well as the introduced marram grass (Douglas & Gainsford 2002; Unsworth et al. 2003). In many instances the focus on the latter is on how to remove it or stop its spread.

In addition to the focus on these sand-binding plants, there has also been an effort to look at ways to encourage the establishment of native plant communities on foredunes and backdunes at a number of localities around the country.

4.6 OTHER SITUATIONS AND TECHNIQUES

In addition to specific work on mines and road sites trial work is now beginning on other highly degraded or hard sites such as quarries and urban subdivisions. While revegetation of these sites is not something new, the focus of these trials is to find low-cost rapid-establishment techniques for getting native plants established in these highly modified environments. These trials are using a combination of techniques such as hydroseeding, mulching, and more traditional plant establishment.

4.7 KNOWLEDGE SOURCES

In the 1980s and 90s, significant knowledge based on both anecdotal and measured evidence was captured and made available in various ways. There are a large number of publications or technical handbooks that outline aspects of what, where and how to plant native plants in revegetation efforts (e.g. Davis & Meurk 2001; Simcock et al. 2005). In addition, there are numerous regional and local resources for providing guidance on what native plants to plant, where to plant them, how to propagate, maintain and manage them (e.g. Auckland Regional Council, Environment Waikato, Northland Regional Council, Dexcel (Clean Streams programme)). Most of these tend to be focussed on managed landscapes (i.e. farmland) and around waterways (riparian planting). While many of these have biodiversity/ecological enhancement as their primary outcome focus rather than E&SC, they nevertheless provide a valuable resource for information.

Several technical bulletins have been produced by the CDVN and can be purchased from ENSIS.

- "Pingao on Coastal Sand Dunes: Guidelines for Seed Collection, propagation and establishment", by David Bergin and JW Herbert
- "Spinifex on Coastal Sand Dunes: Guidelines for Seed Collection, Propagation and Establishment", by David Bergin
- "Sand Tussock on Coastal Sand Dunes: Guidelines for Seed Collection, Propagation and Establishment", by David Bergin
- "Coastal Sand Dunes: Form and Function", by Patrick A. Hesp

More recently, the Internet has opened up useful sources of information. The most relevant of these is through the NZ Ecological Restoration Network (NZERN). Their online resource contains information about native plants, particularly their details and propagation (http://www.bush.org.nz/plantgrow/). "PlanterGuide" is an online tool that enables the user to select a range of plants for use depending on where they are in the country and what the specific site requirements of their site are (http://www.bush.org.nz/planterguide/).

In contrast however, there is currently no single up-to-date resource whose principal aim is to provide information on the use of New Zealand's native plants for E&SC other than the earlier 1986 *Plant Materials Handbook for Soil Conservation Volume 3: Native Plants* (Pollock 1986).

5. WHAT WE SHOULD KNOW

While we have made significant advances in our understanding of the ecological aspects of many of our native plants systems, there is still a lack of fundamental information and understanding on the performance of these species for functional uses outside of their ecological niches. If we are to use native plants in roles that they may not be naturally adapted to, or wish them to grow in habitats that may be unfamiliar, then further research and investigation is required.

Even though there are many hundreds if not thousands of community-based and private restoration efforts underway in New Zealand, most do not carry out any monitoring or evaluation of how they are performing. Collecting fundamental data such as mortality/survival, plant growth (size, dbh, height, spread), density, ground cover, regeneration, phenology etc. is crucial to ensuring that those efforts do contribute to the viability of our natural heritage, particularly in highly modified cultural landscapes.

In addition, if we are serious about restoring the balance and introducing more native plants into our landscapes then one of the things we need to do is begin to explore the possibilities of using native plants for specific roles in E&SC. To do that, we will need to invest more in research on understanding what plants are best for what roles (root reinforcement, sediment stripping from runoff, groundcover expansion, fast establishment etc.), in what combinations, and how they should be applied.

As outlined above, we have only just scratched the surface of our understanding of the use of native plants in these roles. Specific attention needs to be focussed on:

- How do we get native plants to grow faster?
- How do we get more viable seed?
- When is the best time to collect seed?
- How and why native seeds lie dormant and how should seeds be stored?
- Can we promote faster germination and growth?
- Can we get native plants to grow better from cuttings?
- What native plants are best suited to hydroseeding?
- What is the role of soil fungi? How crucial is it?
- What's the best way of getting beneficial soil fungi into your rehabilitation project site?
- What application systems work the best for different sites? Mines, roads, streambanks, construction sites, urban areas?
- Can we invent a native ready-lawn?
- How can native plants be incorporated into traditional and emerging E&SC products?
- Can we play with the ecological mix to get high-performance systems to perform specific E&SC functions?

- How do we capture and share the experiential and tacit knowledge that exists about native plants by those in the community?
- How do we manage issues around commercial advantage (IP) versus public good?

6. CONCLUSIONS

The value of New Zealand's indigenous flora in managed landscapes outside of national parks and reserves has gained increasing attention in the last decade or so. However, while the understanding about the general ecology of many of our plant systems is relatively well-known the use of these plants for restoration and rehabilitation outside of their normal habitat is set against a paucity of quantitative information and knowledge. Limited research resources have been focussed on the use of our native plant materials for use in many of these situations such that most of our knowledge about the performance of these plants or the ways in which they are used is largely anecdotal and often based on trial and error.

There are signs that this lack of data is beginning to be addressed with mining, roading and construction industries turning their attention to the use of more "natural' methods for land stabilisation and vegetation management. In addition, the significant groundswell of community action to bring more indigenous biodiversity into New Zealand's cultural landscapes through riparian planting programmes, wetland restoration, and forest restoration has seen the emergence of networks of knowledge sharing and the start of more quantitative data collection on the performance of many of our native plants in these roles.

There is still a long way to go before we can reach into our toolbox of native plants and select a plant or a plant system to perform a particular E&SC function with any degree of confidence. For this to be realised, we will need to invest more in research and investigation, as well as find better ways to harness and share what we already know.

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