POPLARS AND WILLOWS FOR SOIL EROSION CONTROL IN NEW ZEALAND

A.G. WILKINSON, THE HORTICULTURAL AND FOOD RESEARCH INSTITUTE OF NEW ZEALAND, PALMERSTON NORTH, NEW ZEALAND

ABSTRACT

Poplars and willows are exotic to New Zealand and have been introduced over the last 160 years for hill country soil erosion control, riverbank protection, shade, windbreaks and woodlot forestry. During the 1960's and 1970s over two million poplars were planted in government subsidised planting has declined dramatically in the late 1980's and 1990's with the emphasis shifting to sustainable land management systems. Radiata pine afforestation, poplar silvipastoral systems, and various plant combinations including poplars and willows for riparian management were introduced. To prevent long-term degradation by soil erosion, there is a need to develop economic poplar silvipastoral systems on at least one million hectares of New Zealand pastoral lands. New Zealand research effort is refocusing on obtaining the necessary information to ensure that this is a viable option for farmers.

Key words: New Zealand, poplar, willows, erosion control

INTRODUCTION

New Zealand is a mountainous country situated in the south-west Pacific Ocean. It consists of two main Islands, the North and South Island and several small islands. The nearest continent is Australia, some 1900 km to the west. The country extends between latitude 34.5 S and 47 S and is over 1600 kilometers in length, but only 320 km wide at its widest point. In total area it covers 266,770 km^2. Throughout the length of both islands runs a high mountain range with several peaks over 3000 m high. Because of New Zealand's mountainous nature, rivers are short, flowing swiftly to the sea.

The climate ranges from warm-temperate in the north to cool-temperate in the south. Except for a small semi-arid region in the rain shadow of the Southern Alps of the South Island, the climate is oceanic and windy, with a rainfall of 1000-2500 mm per year. Rainfall is evenly distributed throughout the year although short summer droughts can occur in some areas. High intensity rainstorms can occur at any time of the year, e.g. during cyclone Bola in 1987, 300-800 mm fell over 48 hours.

New Zealand rock types are mainly sedimentary in origin, composed of mudstones and sandstones, the former being highly erodible. The mountain ranges consist prinicpally of greywacke fractured by frequent earthquakes along major faultlines, while the central volcanic plateau of the North Island is covered by deep erodible ash showers. Natural geological erosion rates are high in many areas.

Before European settlement some 160 years ago, most of the country (66%) was originally in dense forest and scrublands. The rapid exploitation of forest resources and conversion to farmland by burning and oversowing with grass seed brought about a wide expanse of largely treeless, exotic grassland covering some 7.3 million hectares, and grassland/scrub and grassland/forest associations covering another 4.3 million ha.

This transformation of forest to grassland on

hill country with steep slopes and erodible soils, subject to high intensity rainfalls, coupled with ill-conceived management practices of periodic burning and overgrazing of New Zealand's native tussock grasslands, resulted in increased runoff and accelerated erosion. The seriousness of the early problems of flooding and erosion resulted in central Government legislation setting up a national authority to make provision for the conservation of soil resources, the prevention of erosion damage and the control of flooding. In all main river systems, Catchment Authorities were constituted to implement a programme of river control in the flood plains and erosion control in the hills and steepland headwaters. Over the last decade new environmental legislation (The Resource Management Act 1991) has been passed by central Government and environmental and land use planning developed to Regional Councils with boundaries similar to the previous Catchment Boards but amalgamating some of the smaller Boards with larger mostly urban community interests. The Act empowers local authorities to control the effects of land use as necessary to promote sustainable management, including minimising the harmful effects of soil erosion. MAF Policy 1995 produced an excellent technical paper on the control of soil erosion on farmland, summarising erosion's impact on New Zealand agriculture, and farm management practices which counteract it. Poplars and willows play a major role in erosion control techniques mentioned in this report.

The sustainability of pastoral production in New Zealand will be dependant on more tree planting in the future. Landcare Research studies have shown that only 8.4 million ha out of a total 26.5 million ha of New Zealand are capable of physically sustainable pastoral and cropping uses without soil conservation measures being applied. Another 7.6 million ha requires farm woodlots and wide spaced tree plantings and/or other soil conservation measures, if physically sustainable pastoral use is to be maintained. This applies to 32% of the North Island and 25% of the South Island. Poplars and tree willows have an obvious role to play, as multi-purpose trees compatible with pastoral systems because of limited impact on pasture production.

For erosion control, soil conservation techniques such as pasture furrows, graded banks, grassed waterways, flood regulating and gully control dams and the use of improved grasses, legumes and trees, have been tried and some practices adaped to meet the special conditions of the hill country farming system of New Zealand.

On this steep unstable hill country tree planting plays an important role with the main spcies being *Pinus radiata* for reafforestation of the worst-eroded areas, and poplars and tree willows in less-eroded areas where continued grazing is still possible. Shrub willows were used principally for streambank erosion control in areas of active scouring. This paper discusses only the role played by poplars and willows in the development of silvopastoral systems with a major soil conservation component. Poplars and willows have been the most widely used trees for planting on unstable hillsides, under pastoral farming conditions, for the following reasons:

1. Easy vegetative propagation of clones of known quality, New clones with superior characteristics such as improved disease resistance have been multiplied rapidly by stem cuttings in local authority and private nurseries and by individual farmers.

2. Poplars and tree willows (also planes *Platanus* sp.) can be established from large unrooted poles in the presence of domestic stock on grazing land. Plastic pole protectors have been developed to provide protection for the first 5-7

years from sheep, goats and cattle.

3. Their early growth rate is superior to all cool temperate tree species other than a few eucalypt species. Height growth from poles varies from 1 to 4 metres per annum for the first five years after planting, depending on soil fertility and moisture regimes.

4. The willows and many poplars are tolerant of flooding and periodically saturated soils. Some poplars species such as *P.deltoidea* spp. *deltoides* (syn. *angulata*), *P.alba* and *alba* x aspen hybrids such as x *tomentosa* and x *alba* x *glandulosa*, and many balsam poplars, are difficult to establish from unrooted material in saturated clay soils. *P.nigra, P.* x *euramericana* and *P.angustifolia* establish better than the previous poplars, on more saturated soils.

5. Poplars and tree willows have extensive root systems capable of rapidly stablishing large soil masses, with across and downslope annual extension similar to annual height increment (in metres) and upslope extension occurring at about half of that rate. Most species can regenerate new trees, in the absence of grazing animals. from residual root systems and stumps whenever the tree has been damaged by live-stock, fire or erosion. Aspen and white poplars are well known for their root-suckering but the North American narrow-leafed cottonwood (*P.angustifolia*), and Californian provenances of *P.trichocarpa* are also prolific suckering species.

6. The fine fibrous root mat of willows has proven most effective for reducing bank erosion and channel scouring or deepening of streams and hillside waterways. A high proportion of fine fibrous roots is stronger and more effective in binding an erosion-prone soil mass together than the larger rope-like roots of some poplr species and cultivars. *P.angustifolia* has proven in the last year to have the capability of producing a mass of fibrous roots when unrooted flowering branches were kept in still and finally, stagnant water for four months. This indicates major possibilities for developing this species for erosion control.

7. Poplars and tree willows have high evapo-transpiration rates during the growing season and are well-known by farmers for their ability to dry out swampy soils. In New Zealand, to obtain the maximum benefit from evapo-transpiration we have concentrated on selecting clones with late leaf-fall in late May-early June. Because of the importance of the Spring grass growth to pastoral farmers, it is essential to consider the consequences of selection of early-leafing clones for silvipastoral system.

8. Poplars and willows provide shade, shelter and supplementary fodder for stock. Foliage can be pruned from wide-spaced trees and windbreaks and fed to stock during summer droughts or it can be produced as coppice shoots from high density plantings used to filter waste water or better utilise wet soils on dairy farms. Prunings are similar in nutritive value to lucerne/alfalfa hay and are rich in nitorgen, potassium, calcium, copper, selenium and zinc.

   Recent grazing trials with sheep, cattle, goats and deer indicate differing preferences between stock types and between poplar and willow species.

9. Timber from well-managed poplar trees (grown straight and pruned) is suitable for a variety of purposes. In New Zealand poplars have been used for farm gates, fence posts and battens, truck and bridge decking, stock crates, stockyard rails, shoes, kitchen utensils, internal building construction, panelling, mouldings,

doors, furniture, veneers, fibreboard (in a mix with *Pinus radiata*) and match production. Currently the amount of poplar timber used in New Zealand is small (< 3000 m^3 per year) because of the scattered distribution of the resource and the predominance of Radiata pine as New Zealand's premier general purpose timber species but the size and use of the poplar resource is beginning to grow as more farmers, sawmillers and cabinet makers become aware of its potential. The utilisation potential for tree willows is not well-known in New Zealand but the tree willow *Salix matsudana* and several of its hybrids with *Salix alba* have sufficiently high basic densities (400-480 kg/m^3) and good wood strength properties that they could also be used for sawn timber and veneer production. There is an untapped opportunity in New Zealand to develop large plantations of poplars, willows and wattles (*Acacia* spp.) for stopbank/levee protection on the wide bermlands of the eastern South Island rivers with coppice crops of fibre and chips combined with log production for local sawmills, fibreboard and veneer factories.

PLANTING PATTERNS

The techniques of tree planting to reduce erosion on farmland have evolved into the following systems:

1. Close planting

Trees have been planted at minimum spacings of 3x2m. The more actively eroding and unstable sites are planted with poplars and willows, usually unrooted 1m-long stakes, and the remainder with *Pinus radiata*. This type of planting offers maximum protection and the most rapid stabilisation of the area. It is often linked to the contruction of wooden or pole and netting debris-retention dams in stream channels. These areas may be planted and managed as farm woodlots with the dual purpose of erosion control and timber production.

In New Zealand, I suggest that *P.* x *alba* x *glandulosa* Yeogi 1, *P.* x *tomentosa*, and possibly, new clones of *P.angustifolia* x fastigiate *P. nigra* are the most appropriate poplars to use for these close spacings. The spacings for poplars and tree willows would also be better widened to 4x4 m with interplanting of shade-tolerant native plants or blackwood (*Acacia melanoxylon*).

2. Wide-spaced hillslope planting

On partly unstable areas, where stock are not excluded, 1-year-old trees or stakes are too vulnerable to browsing damage, so hybrid poplars and tree willows (mainly *S.matsudana* and *S.matsudana* x *alba*) are planted as 3m-long unrooted poles at densities from 25 to 100 stems/hectare. Most hillsides do not require complete coverage and poles may be planted only at strategic positions on unstable areas such as springs or seepages. Where possible cattle are withheld from grazing the area for two to four years and only sheep allowed in these paddocks until the poles are well-established. The advent of plastic tubular protectors has allowed lighter cattle and goats to graze the area from year one but it is better to keep out heavier cattle for at least two years.

3. Change of slope planting

Often slips are initiated just below gently sloping flats or hill crests where downhill slopes become steeper, often due to seepage water from the flats flowing out over impervious layers. One or two rows of poplars or tree willows spaced some 8 to 12 metere apart are planted in this change of slope area.

4. Pair planting and single row channel planting

Pairs of tree willow and/or poplar poles are planted at intervals of 5 to 20 m apart along small streams or channels where runoff concentrates in heavy rainstorms. The poles are planted directly opposite each other. Poles may also be planted on alternate banks or directly in collapsing tunnel gullies. Tree willows initially provide an erosion-resistant mat of roots in the stream or gully, preventing scouring, maintaining bank stability and thus the stability of the hillslopes above. Experience suggests that it would be less risky, to alternate poplars and tree willows to combine the root system effects and spread the disease and pest risk to these largely monoclonal plantings. Tree willows planted as poles have become multi-stemmed and some 10-20 years later have broken apart, blocking narrow channels and increasing bank scouring. To avoid this it may be necessary to top the willows for regular fodder production on a 3 to 5-year cycle or to prune poles to a single leader. Too dense plantings often shade out underlying pasture and wider spacings or pruning may be necessary to maintain the erosion prevention effects of pastoral ground cover.

5. Stream and riverbank planting

For streambank protection, willows are planted in closely spaced lines along sections of the stream where bank erosion is likely to occur. Once established they prevent further undercutting of the banks. In meandering streams only the outside of bends are planted. A similar pattern is used along the major rivers for stopbank protection. Here anchored tree willow logs are used to reduce scouring and assist the close-spaced plants to establish. As the tree willows grow they are partially cut through, up to two thirds of the circumference, and layered, so that a dense thicket of new stems continues to provide front-line protection while the residual root system prevents/ .reduces bank undercutting.

6. Block planting

A block of willows and/or poplars is planted 4 or 5 rows deep across the streambed to create a strong point in gullies and streams and prevent degrading where small waterfalls are working back up the channel. They also trap silt and debris on the gully floor. Tree and shrub willows are better - suited to this role than most poplars.

7. Periphery planting

In very unstable active gullies the direct establishment of plant materials is very difficult. Small rooted trees cannot withstand the soil movement. In these cases suckering poplars such as *P.alba, P* x *alba* x *glandulosa, P. angustifolia* and *P.trichocarpa*, and the black locust *Robinia pseudoacacia* can be planted along the more stable edges of the gully. If further movement occurs these trees may be carried down to the gully floor where broken roots will send up suckers. When the gully bottom is sufficiently stabilised, further planting can be undertaken on the gully bottom and up the sides.

8. Shelter or windbreak planting

Usually one row of poplars or tree willows are planted to shelter livestock or crops or protect fields against wind erosion. Prior to the arrival in New Zealand in 173 of the poplar leaf rust *Melampsora larici-populina*, the Lombardy poplar *Populus nigra*'Italica' was the most widely used clone for this purpose. Because of its high susceptibility to this leaf rust the clone was replaced by hybrid tree willows (*S.matsudana* x *alba*) and more recently by the *P.* x *euramericana* clones Tasman, Veronese and Crow's Nest. Poplars and willows have been used extensively for horticultural shelter because of their ease of

establishment and rapid growth rates but alders are now preferred for internal orchard windbreaks because of their more confined root spread and N-fixing ability. Spacings within rows vary from 1-2 metres (horticulture) to 2 to 5 metres (farms). At the wider spacings suitable small evergreen trees or shrubs may be interplanted to reduce ground drafts.

9. Fenceline planting

In the past, poplar poles or two-year-old rooted trees were planted at 5 metre intervals along proposed fencelines on unstable country. When planted 2 to 4 years before erecting the fence, the trees acted as live fence posts. This system worked well but has mostly been replaced by the use of lighter and cheaper electric fencing.

On most farms a combination of woodlot and riparian retirement forestry, line plantings and wide spaced plantings is required in conjunction with other soil conservation techniques and management changes. Regional Councils offer planning assistance and a few still offer some financial subsidies for erosion control.

To encourage higher tree planting rates research and demonstration is currently focusing on the economics and biophysical sustainability of poplar silvipastoral systems.

In most countries where poplars and willows are used for erosion control they are planted either as unrooted stakes or cuttings, or one to two-year-old rooted trees. The practice of using unrooted poles in the presence of grazing animals is the most significant feature of poplar and tree willow planting in New Zealand and has led to some special problems in selection and propagation.

Species Selection

The study of the various aspects of poplar and willow selection and cultivation is undertaken by HortResearch, with the New Zealand Forest Research Institute providing inputs in wood utilisation and timber yield table development.

A poplar and willow nursery is maintained by HortResearch in Palmerston North where the following work is carried out:

1. Collection, identification and classification of all poplars and willows grown in New Zealand

The national poplar coppice stoolbed collection contains 92 imported clones, 61 clones selected from imported seedlots of pure species and 33 clones selected from interspecific and inter-provenance hybrids bred in New Zealand between 1978 and 1995. Over 500 additional clones are held on farms for future breeding or reselection.

The national willow coppice stoolbed collection contains 102 imported tree willow clones, 25 NZ-bred hybrid tree willows, 96 imported shrub/osier clones and 27 NZ-bred shrub willows.

Certified material is distributed to commercial and Regional Council nurseries and private growers. Stock and stoolbeds of the larger nurseries may be inspected for varietal control and incidence of disease, at the request of the grower.

2. Introduction and testing of clones and seedlots

Clones and seedlots are introduced only under permit, through a two year quarantine system that includes screening of introduced clones for viruses. Material introduced by HortResearch and released from quarantine then undergoes the same

selection prodcedures as seedlings grown from introduced seed of pure species or hybrid seed from a small controlled-hybridisation programme.

3. Controlled hybridisation

No introduced species has yet fulfilled all the requirements considered essential for erosion control and silvipastoral systems. A controlled hybridisation and vegetative propagation programme is in progress to combine the most useful features of introduced species into better-adapted F1 and backcross combinations.

Selection criteria

High disease and pest resistance. At present this involves for poplars, selection for resistance to two *Melampsora* rust species and races, and to *Marssonina brunnea*. Diseases of willows in New Zealand include at least two rusts *Melampsora coleosporioides* and *M.epitea* and variants of *M.epitea*, and *Marssonina salicicola*. There are no serious insect pest problems in New Zealand, but several very damaging insect pests occur in the Northern Hemisphere. The Asian white-spotted tussock moth *Orygia thyellina* has just been reported in Auckland in the North Island. Since chemical control measures are rarely economic for soil conservation and agroforestry plantings, all clones must be selected for resistance and/or tolerance to the current range of pests and diseases in New Zealand. To provide early warning of the threat of new pests and diseases, New Zealand-bred clones have been sent to countries where poplars and their pests and pathogens are native. In addition our long-term strategy is to obtain improved disease and pest-resistant selections from overseas programmes to make sure that our base gene pool incorporates a wide range of resistance genes.

Ability to grow from stem cuttings. Poplars are planted into pasture as 3m-long unrooted poles cut on a two to three year rotation from specialised pole production stoolbed nurseries. Rooted trees in New Zealand are principally used to establish windbreaks. Some problems have been encountered with rooting cuttings and poles of *P.deltoides, P.trichocarpa, P.alba* and *P.* x *glandulosa* and cuttings of *Chosenia bracteosa* and *Salix urbaniana*, but clones of hybrid black and balsam poplars and most willows generally root easily.

Straight stem form. Since poles must be stacked in the nursery, on trucks and under helicopters, and, in most cases now, are planted by ramming them directly into saturated soils, stem straightness is an essential requirement for ease of handling and reduced cost during nursery production and planting. Where the trees are grown for timber, straight stems of poplar are giving higher sawing recoveries (Up to 60% compared to 30-40%) due to less tension wood. This should be kept in mind when farmers are planting double or single rows along narrow roads or canal banks. Clones like *P.* x *euramericana* I 214, Flevo, and Dorskamp used for this type of planting, react badly and are likely to yield poor timber.

Vigour. Clones grown for soil conservation must possess rapid initial growth rates of both the stem and roots to effect rapid soil stabilization and to place the leading shoot out of reach of sheep and cattle. Total growth is greatly affected by the widely differing photoperiod and wider temperature requirements of poplars and willows from different latitudes and altitudes and careful provenance selection is required to obtain clones capable of utilising the full growing season in the various regions of New Zealand. Hybrid clones, selected for vigour in the milder North Island of New Zealand by choosing clones that hold their foliage into late autumn, have suffered freezing

and bacterial damage when transferred into inland South Island areas which experience late Spring and Summer frosts.

Fibrous root systems. Fine fibrous roots have a greater binding effect on sandy soils. fine gravels and free-draining volcanic ashes and pumice. In conjunction with an extensive network of large diameter roots they provide excellent reinforcement of unstable clay loam hill country soils. However, tree willows tend to have a better root system for lining rapidly eroding channels and a combination of poplars and willows is often necessary to provide the best erosion control.

Unplantability to the Australian brush-tailed possum (*Trichosurus vulpecula*). Poplar foliage, bark and buds varies greatly between species in attractiveness and palatability to possums. Establishment of palatable clones, particularly of the black poplars and European white willow (*Salix alba*), may be prevented or seriously retarded by possum browsing. *Salix matsudana* and *S.matsudana* x *alba* hybrids vary from medium to high palatability to possums and some clones have also sufferred establishment problems. *Salix pentandra*, a slower-growing tree willow, has proven less palatable and is being used in crosses with *S.matsudana* to generate new low palatability tree willows for erosion control planting.

Early development of rough bark on the lower trunk. Poplar and tree willow species have barks of widely differing thickness and texture. Most varieties of *P.deltoides* and some forms of *Salix nigra* develop a thick rough bark within the first 5 years of growth, while other species such as *P.cathayana, ciliata,* and *maximowiczii* and *S.alba* may retain a thin smooth bark for 10-20 years. Cattle often ring-bark smooth-barked trees causing severe damage or death. unrooted 3m-poles planted in New Zealand are protected by plastic netting sleeves or tubes for the first 5-6 years before the tree bursts the protector allowing stock access to the bark. Current breeding is focused on hybridising *deltoides* with *angustifolia*, a rought-barked balsam poplar from the USA, and a new rought-barked *S.matsudana* clone with *S.pentandra* to develop possum-resistant hybrids with ealy formation of rough bark.

Resistance to wind damage. To miminise wind damage, selection has focused on eliminating clones which show wind-breakage on young trees and in coppice stoolbeds. It is apparent under field conditions that large-leafed species (e.g. southern forms of *deltoides*) and/or clones within hybrid families, are prone to breakage where individuals have heavy thick branches with steep-angled forks in the main leader. This also applies to multi-stemmed tree willows grown from poles. For erosion-control trees, grown at wide spacings in open pasture on windy sites (most of New Zealand), preferred clones have a narrow crown and a multinodal habit, i.e., there are a large number of small branches between the major whorls put out at the commencement of the new seasons growth. The effect of branch habit is modified by stem strength, some wide-crowned, uninodal clones, such as *P.* x *euramericana* Triplo and *P.deltoides* G48, fracture and break more easily than others with similar crown form.

Other charcteristics (optional). These depend on the purpose and site conditions. *Sex* Male clones are preferred for riverbank planting to reduce seedling establishment in riverbeds. Crack willow *S.fragilis* is notorious in New Zealand for its tendency to re-establish on sand and gravel bars in braided river channels from small broken branches as well as hybrid seedlings. The resultant growth diverts river flows and suppresses native plant regrowth. This species, along with the shrub willow *S.cinerea* have been highlighted as weed species and any further imports are restricted. Male plant are also preferred for both poplars and willows used for horticultural windbreaks, roadside and urban plantings to avoid the nuisance value of

poplar cotton.

Ability to tolerate acid, saline or low fertility soils. Unpublished small-sclae trials in New Zealand have indicated that *yunnanensis* can root in pH 4.5 and that *nigra* Italica has a high tolerance of salinity. *P.* x *alba* x *glandulosa* Yeogi 1 also has a wide tolerance of pH extremes.

Ability to produce sucker shoots from damaged root systems. This is most developed in aspen and white poplars but is also typical of *trichocarpa* from California and *angustifolia* from the Rocky Mountains, USA. In all these species, suckering occurs without initiation by damage to the root system. This tendency to sucker can be controlled by hyridization with *P.deltoides*. Hybrids of *angustifolia* with *P.nigra* Italica and *nigra* Thevestina have continued to sucker.

Ability to grow on drier soil types. Aspen are reputed to be the most tolerant. In New Zealand *P.alba* x *glandulosa* Yeogi 1 from Korea has shown the best tolerance of dry soils under field conditions.

Poplars

In the past twenty years the balance of clones grown for pole planting has continued to change from the early releases of *Melampsora* rust-resistant *P.* x *euramericana* Flevo, I 154, Tasman and Veronese and possum-resistant *P.trichocarpa* PN 471 and *P.deltoides* x *maximowiczii* Eridano, to the 1995 releases of the new NZ-bred, possum-resistant, hybrid black x balsam poplar timber clones Toa and Pakai, an 13 more wind-resistant but medium-palatable hybrid black poplars. The latter include one very rough-barked clone Argyle which develops rough bark within three years and is being recommended for use where an early return to cattle grazing is top farm priority.

Table 1, Poplar stool numbers, Council and Commercial, 1995, illustrates clearly the predominance of three clones, Tasman, Veronese and Kawa (the first NZ-bred hybrid black x balsam poplar).

This poses a large disease risk similar to the situation prior to the arrival of the poplar rusts in 1973. At that time the majority of soil conservation planting focused on the hybrid black poplar clones I 78 and I 214. These had to be withdrawn from planting completely in higher rainfll areas. Veronese is already being attacked by new races of *Melampsora larici-populina* and may need to be restricted to regions with low summer humidity.

The problem with browsing damage by possums has largely been overcome by breeding less palatable cultivars with the proportion of palatable cultivars dropping from 93.6% in 1972 to 55% in 1996 and likely to drop further as the advantages of the new possum-resistant cultivars become better known.

Willows

Willows are widely utilized in New Zealand for river and streambank protection, and during the 1970's and early 1980's thousands of poles of the tree willow *Salix matsudana*, and NZ bred hybrids with *S.alba*, were planted for hill country soil conservation. These clones initially substitued for the rust-susceptible, Italian hybrid black poplars but have gradually lost favour as disease-and possum-resistant poplars have become available. Some 255,000 stools of tree willows and 18,000 stools of shrub and osier willows are being grown in stool nurseries in New Zealand, compared to 351,000 poplars. The number of tree willows planted for hillside stabilization is likely to decline until new possum-resistant cultivars become available. River engineers in New Zealand have differing preference with a couple of clones of crack willow (*S. fragilis*) and golden willow (*S.alba* var. *vitellina*) still being widely used with little regard for their sex and potential spread.

Table 1. Poplar Stool Numbers, Council and Commercial, 1995.

Nursery	Black Poplar Hybrids									Balsam Poplars and Hybrids								Yeogi	Total
	Italian	Flevo	Tasman	Veronese	L.Avanzo	Argyl	Crows Nest	Italica X's	Man. Gold	Yunnan	Tricho.	Eridano	Kawa	Toa	Pakal	Schrelner	Other		
Walkato	0	0	5400	3350	0	0	0	0	0	11550	0	0	15850	4170	0	0	0	0	40320
Bay of plenty	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taranakl	0	0	0	0	0	0	0	0	0	2300	0	1010	1200	450	0	0	0	0	4960
Gisborne	2200	12500	1000	1550	450	0	0	500	0	0	0	6550	1500	1450	650	0	0	0	28350
Hawkes Bay	0	0	0	4600	0	170	290	500	25	5000	0	400	13600	1762	0	0	25	0	26372
Manawalu	0	0	1200	2880	0	0	80	0	0	450	1200	7300	11350	350	0	0	0	0	24810
Wellington	0	500	7000	30420	2610	1730	2940	9410	0	0	0	5050	3480	6320	3050	0	298	700	73508
Commercial	0	3035	4210	16800	200	1000	2700	4050	550	3305	0	1220	18200	5055	880	0	3550	200	64955
NI Total	2200	16035	18810	59600	3260	2900	6010	14460	575	22605	1200	21530	65180	19557	4580	0	3873	900	263275
Tasman	0	942	1136	144	0	150	0	138	0	0	0	603	303	155	147	0	0	500	4218
Marlborough	0	0	0	0	0	23	0	73	0	0	0	0	326	229	208	0	205	211	1275
Otago	0	2500	7360	3100	1750	1200	0	0	0	200	0	200	0	0	0	400	0	0	16710
Commercial	2700	7650	22305	9720	480	890	5705	520	220	1480	70	5380	5453	320	170	2100	100	110	65373
SI Total	2700	11092	30801	12964	2230	2263	5705	731	220	1680	70	6183	6082	704	525	2500	305	821	87576
NZ Total	4900	27127	49611	72564	5490	5163	11715	15191	795	24285	1270	27713	71262	20261	5105	2500	4178	1721	350851

A shrub willow selection programme in the 1970's and early 1980's produced improved male clones and clonal mixes for torrent control and bank protection planting. Most emphasis was placed on male, possum-resistant clones of *S.purpurea*, the most useful being *S.purpurea* Irette. These clones and clonal mixes supplement the previously favoured, 'possum-resistant'. *S.purpurea* Booth which has been widely used for streambank and gully protection. However, as for the poplars and tree willows, the genetic base is very narrow and greater advances in erosion control and utilization could be made by undertaking wider provenance introductions of promising species.

POPLAR AND WILLOW PROPAGATION AND ESTABLISHMENT

1. Type and size of planting material

For erosion control and most new poplar woodlot plantings, poplars and willows are planted principally as unrooted stakes and poles. The use of one-year-old rooted cuttings is now confined to the establishment of shelterbelts, some woodlots, and for river bermland protection/production plantations. The propagation of rooted stock follow normal nursery practice with cuttings lined out at 25 cm x 1 m spacing. At the end of the growing season trees are undercut with a U-shaped blade, lifted, pruned, root-trimmed and despatched. This technique produces trees from 2 to 4 metres in height and for the production of larger numbers of smaller 1 m stock it is necessary to eighter grow small cuttings in containers/root trainers or at close spacings.

Pole production nurseires were previously maintained predominantly by Catchment Authorities but since these were replaced by Regional Councils the number and size of nurseries has declined and private growers are now tending to produce poplars for both timber and erosion control. All of these nurseries utilise cultivars developed and tested by HortResearch in conjunction with a Regional Council's research collective. Varietal control is maintained by the use of a standard colour code applied to poles prior to despatch. In 1995, 165,000 two to three-metre poles were produced compared to 321,000 in 1988. Poles are normally produced on a two to three-year rotation and stools can provide 4 to 6 crops of poles before being replaced (usually by the arrival of improved cultivars). In some Regional Council areas up to 200,000 poles of crack and golden willows are harvested directly from riverbank plantings for use in river control work.

The following types and sizes of planing material are in general use:

Unrooted	Length	Diameter	Prepared from	Use
Wands	1 m	15-25 mm at base	1 yr-old wood	Stream control
Stakes	1 m	20-40 mm at base	1 yr-old wood	Gully control Screen stabilization
Poles - sheep only	2-3 m	40-60 mm at base	2 yr-old wood	Hillside stabilization
- cattle	3 m	60-100 mm at base	2 or 3 yr-old wood	Gully control River control

2. Method of pole production

Stools for pole production are established from hardwood cuttings, the spacing varying from a minimum of 1×1 m to 4×1 m depending on the clone involved, soil and climatic conditions and size of machinery available for inter-row cultivation, spraying, mulching and harvesting. Cuttings are grown into single-leader trees with the first harvest occurring at age two or three years. Clones in current use, with the exception of *Salix matsudana*, produce crops of poles every two years, the number of poles averaging from 1 to 2 per stool for close spacings and 2 to 4 for wide spacings.

Poles are cut in winter from June to August and stoolbeds coppiced at 20-40cm above ground. The final stool height depends on the species and how much stem dieback is expected to occur in the spring following pole harvest. As a general rule *Salix matsudana, Salix alba* and their hybrids, *Populus nigra* and *P.* x *euramericana*, coppice easily and can be cut to a range of heights. Most balsam poplars and *P.deltoides* of southern origins tend to die back and may become severly infected with silverleaf disease caused by the fungus *Chondrostereum purpureum*. Branches are trimmed off manually, the pole topped at 10-15 cm above the junction of the current and last year's growth (the 'growth ring'), and the base cut with a single long slanted cut. Cutting to the growth ring is essential for *P.deltoides*, the balsam poplars and their hybrids, as it encourages sprouting from the top of the pole. The slant-cut base provides stability to poles and prevents rotation of the pole in the ground when the pole is rubbed by sheep and cattle. Both these techniques plus the use of improved plastic protectors and more careful siting have improved survivals from 40-60% in the 1960's to better than 95% on most sites in 1995.

Stumps or stools may be either sprayed or painted with highly effective biological and chemical control applications to reduce silverleaf attack. The commercial value of these techniques to the horticultural industry restricts reporting. Further information is available from Dr.A.G.Spiers, HortResearch, Private Bag 11030, Palmerston North, New Zealand.

Poles are planted as soon as possible after cutting but when this is not possible they can be stored for several weeks in winter by either placing them with their bases in running water (aerated) or by placing them in horizontal stacks with overhead sprinkler irrigation. For most of the southern *P.deltoides*, balsam poplars, *alba* and *alba* x *glandulosa* clones tried in New Zealand, decline in bark viability occurs under anaerobic conditions so that clones of this type are better stored under sprinkler irrigation or planted within one week of cutting. The same problem occurs when these are planted on soil which remains saturated for long periods, resulting in rooting only in the top few centimeters of aerated topsoil. Stock rubbing can then break these surface roots and kill the poles.

3. Pole establishment

Poles are delivered to field locations by truck and spread in bundles across hillsides, often by helicopter. Planting is carried out either by the farmer, or by a planing contractor using specialised pole rammers. Most poles are now protected, from sheep by plastic netting sleeves, and from cattle and goats by tubular plastic protectors. Cattle are excluded from the planted area for two to three growing seasons to allow root systems to establish. Sheep grazing is continuous but it is preferable that sheep are treated for external parasites and shorn before their return to the planted area. This reduces their tendency to rub on the poles and thus break the new roots near the soil surface. In either case it is always necessary to check the poles for looseness and re-ram the topsoil before the main growth phase occurs in early to mid-summer. Willow poles planted for riverbank protection may also be protected from bark damage by floating debris or shifting gravels by the use of the plastic protectors.

Pottential utilization of tree planted for erosion control

1. In most cases hill-country erosion control plantings are scattered with poor logging access; trees have been unpruned, are often multi-stemmed, thus leaning and prone to develop high proportions of tension wood, and have high bacterial wetwood contents. Potential uses of most of this resource are limited to on-farm milling for fencing materials, firewood or lumber for on-farm use. However, it is possible to prune the more accessible plantings into an adequate form for timber and veneer production and current research is attempting to evaluate yields from block-planted vs. wide-spaced vs. line-planted poplars and to ascertain the incidence and causes of bacterial wetwood in New Zealand plantings. Two hybrid black x balsam poplar clones, Eridano and Kawa, appear to have a lower incidence of wetwood compared to *P.* x *euramericana* and *P.trichocarpa* x *deltoides* clones.

2. Where woodlots are established for stopbank protection on river bermland large quantities of poplar and willow wood can be grown for a variety of end uses. At present few suitably-spaced or tended stands have been grown and utilization has been minimal except for the use of some tree willow plantings in the South Island to provide fibre for inclusion in medium-density fiberboard production. In 1995-96 some small trial log shipments of poplar (Oxford, Androscoggin and Rochester) have been harvested from South Island river bank-protection plantings. The Italian hybrid black poplars, I 78 and I 214 have also been harvested from unpruned river planings and manufactured into furniture, wall and ceiling linings.

The future role of poplars and willows in New Zealand

The present emphasis in New Zealand is on the development of biophysically, economically and socially 'sustainable' production systems. Poplars and tree willows have major roles to play;

- as wide-spaced timber and erosion control trees in silvipastoral systems on at least 1 million ha,

- for riparian management (both nutrient-stripping and bank protection)

- and for industrial, city, and dairy effluent treatment combined with fibre or fuelwood production.

A few of the more vigorous shrub willows such as 'Kinuyanagi', *Salix purpurea* and *S.viminalis* may also have a role in short-rotation coppice plantations for effluent treatment and fodder/fuelwood.

Limited research is being undertaken at present to evaluate poplar as a timber tree and to evaluate the feasibility of poplar silvi-pastoral systems. This work is likely to expand as industrial wood users in New Zealand and Pacific Rim countries become aware of the potential production from New Zealand farmland and river systems. The potential value and role of willows to the wood industry is not yet recognized but will be promoted particularly as an economic tool for management of South Island rivers.

REFERENCES FOR FURTHER READING

Collier, K.J., Cooper, A.B., Davies-Colley, R.J. Rutherford, J.C., Smith, C.M., Williamson, R.B. 1995: Managing Riparian Zones: A contribution to protecting New Zealand's rivers and streams: Vol.1: Concepts:p.39 and Vol.2: Guidelines: 142 p. Department of Conservation, Wellington, New Zeland.

Douglas G.B., Bulloch, B.T., Foote, A.G. 1996: Cutting management of willows (*Salix* spp.) and leguminous shrubs for forage during summer. New Zealand Jour. of Agric. Res. Vol.39: 176-184.

Hicks, D.L. 1995. Control of soil erosion on farmland; A summary of erosion's impact on New Zealand agriculture, and farm management practices which couneract it. MAF Policy Technical Paper 95/4, Ministry of Agriculture, Wellington, New Zealand: p.45.

Ministry for the Environment. 1995. Environment 2010 Strategy: A Statement of the Government's Strategy on the Environment. Ministry for the Environment, Wellington, New Zealand; p.63.

New Zealand Poplar Commission. 1995. Poplar agroforestry: An Introduction to using poplars for timber. HortResearch, Palmerston North, New Zealand: 18 p.

Strategic Consultative Group on Sustainable Land Management Research 1995: Science for sustabinable land management: Towards a new agenda and partnership. Ministy of Research, Science and Technology, Wellington, New Zealand: 100 p.

Van Kraayenoord,' C.W.S., R.L. Hathaway (eds.). 1986. Plant Materials Handbook for Soil Conservation. Volume 1: Principles and Practices. HortResearch, Palmerston North, New Zealand. p.296.

Van Kraayenoord, C.W.S., B. Slui, F.B. Knowles. 1995. Introduced forest trees in New Zealand: Recognition, role and seed source: 15. The Willows *Salix* spp. New Zealand Forest Research Institute, FRI Bulletin No.124, 32 p.

West, C.J. 1994. Wild willows in New Zealand. Proceedings of a Willow Control Workshop hosted by Waikato Conservancy, Hamilton. Department of Conservation, Wellington, New Zealand. 103 p.