NZ Grasslands Conference 2011; Paparatu Station field tour

'Poplars and Willows in Hill Country - Soils and Carbon'

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Abstract

Poplar and willow trees have proved effective in reducing soil erosion on pastoral slopes to a minimal level. They achieve this through the development of an extensive root system which achieves its maximum potential when it interconnects with root systems of adjoining trees to form a reinforcing network across a slope. A consideration of spacing is important to achieve soil stability in the shortest possible time. Trees planted to achieve 30% canopy cover will reduce pasture production by around 10% during the period the tree is in leaf. At maturity poplar and willow trees will stabilise soil on slopes at a canopy cover less than 30%, the amount depending on the clone. These trees contribute soil carbon and are eligible for carbon credits under the ETS where the area planted exceeds one hectare and the trees are sufficiently close to achieve 30% canopy cover. Trees vary in form so a consideration of canopy spread will assist in choosing appropriate species and clones for the complementary purposes of soil conservation and carbon storage.

Poplars and willows reduce soil slippage and hence erosion

Poplars and willows and to a lesser extent *Eucalyptus* spp. have been planted on erosion-prone pastoral hill slopes for more than 50 years. Plantings on farms have been used to stabilise gully, earthflow and slope erosion. Depending on the situation the extent of planting and the spacing of trees have varied. As much as 700,000 ha of pastoral land remains unplanted or underplanted with protective trees and so this land area continues to be susceptible to slippage or collapse or gravitational creep ,depending on the erosion issue. Major storm events e.g. Manawatu 2004, Hawke's Bay 2011, Wairarapa 2005, lead to significant erosion of unprotected pastoral hill country. However, the strategic planting of poplar and willow trees can significantly reduce the degree and severity of slippage, earthflow movement and gully scouring. Douglas et al. (2011) reported that spaced conservation trees of various sizes on slopes of mostly 25-30° reduced the extent of soil slippage at 65 sites by an average of 95% compared with slippage on nearby pasture control sites (Figure 1).

Soil slippage occurred at six of the 53 sites with *Populus* trees and at four of these, trees had an average DBH <30 cm (Douglas *et al*. 2011). The relatively low DBH values suggest that slippage at these sites was predominantly because of inadequate root development of individual trees or failure of adjoining tree root systems to interlock significantly, perhaps because spacings were too wide (Douglas *et al.* 2011). Even with treed areas slippage may occur over a short distance, but major slippage with a debris tail to the bottom of the slope was never observed to have originated from within a treed site.

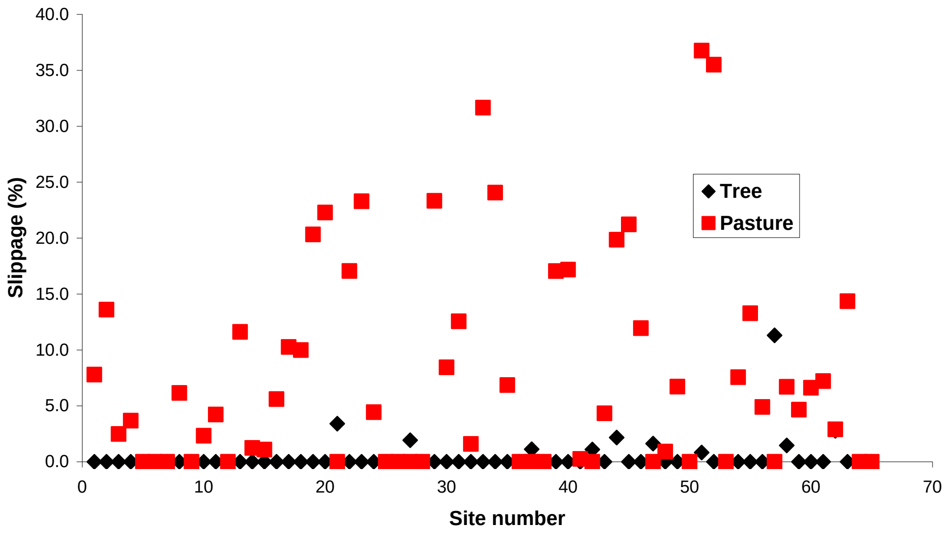

Figure 1. Extent of slippage (%) on tree and pasture sites in Manawatu and Wairarapa in winter 2007 (from Douglas *et al*. 2011)

Tree root systems take time to develop to the extent that they effectively stabilise saturated soil (http://www.poplarandwillow.org.nz/files/poplar-root-developing-and-tree-spacing.pdf). McIvor et al. (2009) showed that root development is correlated with diameter at breast height (DBH) and Douglas et al. (2011) suggest that poplar or willow trees with a DBH >30 cm will stabilise soil within 10 m of the trunk.

Spacing of trees 20 m (2 x 10 m) apart at initial planting will mean that slope protection will not be achieved till those trees have a DBH >30 cm which will take from 9-13 years depending on the site characteristics (soil depth, available moisture, wind exposure etc) and the clonal attributes (tolerance to drought and wind, growth rate). Closer spacing at planting time followed by progressive thinning as the trees grow will achieve rapid soil stabilisation while having minimum impact on pasture production.

Poplar root systems and effectiveness

Poplar root systems extend a long way from the tree and anchor themselves at regular intervals by growing vertical roots called sinker roots into the deeper soil horizons. Figure 1 shows the horizontal distribution of coarse roots for a 9yr old 'Veronese' poplar tree with a DBH of 21.3 cm. While the structural roots of the single tree extend out beyond 10 m, Douglas *et al.* (2011) suggested that there is insufficient root presence or root strength past 10 m to prevent soil slippage.

Figure 2. Root length density for coarse (≥2 mm diameter) roots of a single 9 yr old 'Veronese' poplar tree grown on a pastoral hill slope (from McIvor *et al.* 2008).

However, this does not take account of the contribution of adjacent trees to root presence and hence soil stabilising. Figure 3 shows how spacing influences root length density around each tree, by adding in the contribution of all trees surrounding that tree and assuming they are space-planted across the slope, either 8 m, 10 m or 15 m apart. Two aspects are notable; the closer the spacing the greater the slope protection, and the closer the spacing the earlier slope protection is achieved. The extensiveness of a tree species root system on its own is not as important in stabilising soil and reducing landsliding as the evenness and density distribution of roots across a slope. While root distribution around a single tree may be asymmetrical (McIvor et al. 2008) the contribution of surrounding trees, while not necessarily removing any asymmetry, may create a more even spatial distribution of roots, and the root density across a slope is a function of spacing.

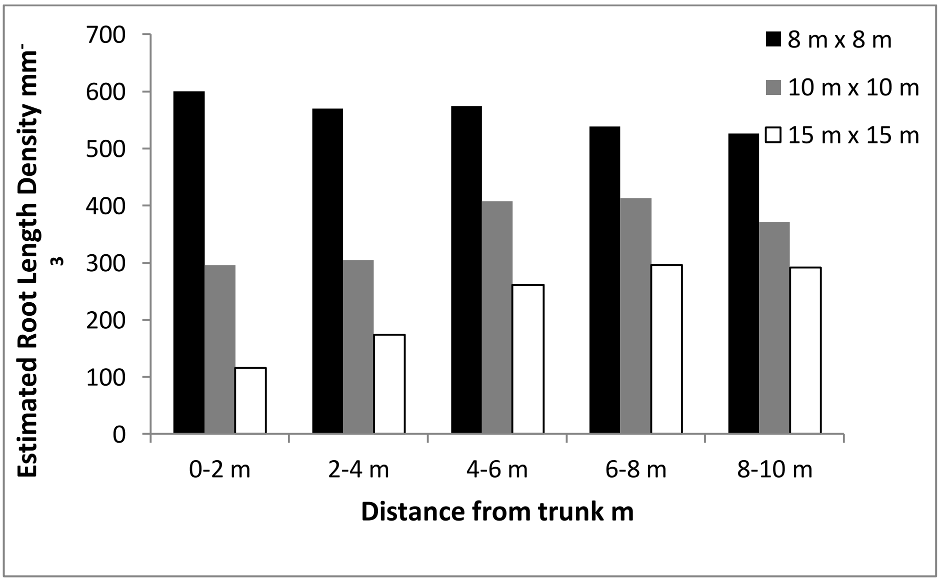

Figure 3. Root length density for coarse roots at different distances from the trunk of a 9 yr old 'Veronese' poplar tree grown at different spacings (from McIvor *et al.* 2008).

Poplars and pasture production

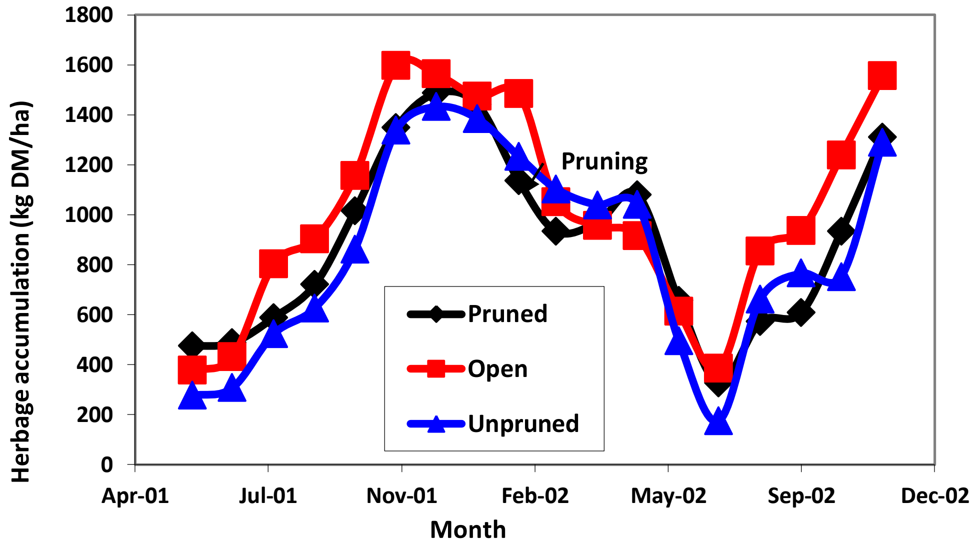

Figure 4. Herbage accumulation under pruned and unpruned 7 yr old 'Veronese' poplar trees growing on a hillslope compared with open ground. Tree spacing was 8 m x 8 m.

Poplar trees will reduce pasture production (Figure 4) the extent depending on canopy spread which, in turn, is dependent on the clone (the narrower the canopy the less the reduction in annual pasture production). Lombardy poplars have almost no effect on pasture growth. Tree shading has a positive effect on pasture growth in late summer through greater retention of soil moisture and cooling of the pasture. Pruning of the trees allows more light to the pasture. Following pruning of the trees in figure 4 radiation to the pasture increased from 66% to 77% of the radiation available to the open pasture. Wider spacing of the trees will also enhance pasture production. Assuming 30% canopy cover (the ETS requirement) overall pasture production would decrease from 100% (open pasture) to 93-89%, depending on whether the trees are pruned or left un-pruned.

Once slippage has occurred on a pastoral slope recovery of production is unlikely to improve beyond 80% of the uneroded slope (Rosser and Ross 2011), such a recovery taking up to 80 years. Topsoil, once lost, takes a long time to re-form. Investment in strategic planting of poplars and willows will retain the topsoil which is a primary capital asset. It is well to consider other benefits conferred by the trees. They maintain and enrich the soil carbon and contribute to soil nitrogen through root breakdown, root exudates and the action of endophytic nitrogen fixing bacteria (Doty *et al.* 2005). Lateral roots aerate the soil assisting root penetration by pasture grasses, and increasing water storage. Shelter promotes grass growth and shelter and shade ease environmental stresses on stock, reduce maintenance feed requirements, and promote growth.

Poplars, willows and the ETS

Established soil conservation plantings of both poplars and willows provide an opportunity to claim carbon credits under the Emission Trading Scheme. The requirements are well documented on the MAF website (http://www.maf.govt.nz/forestry/forestry-in-the-ets).

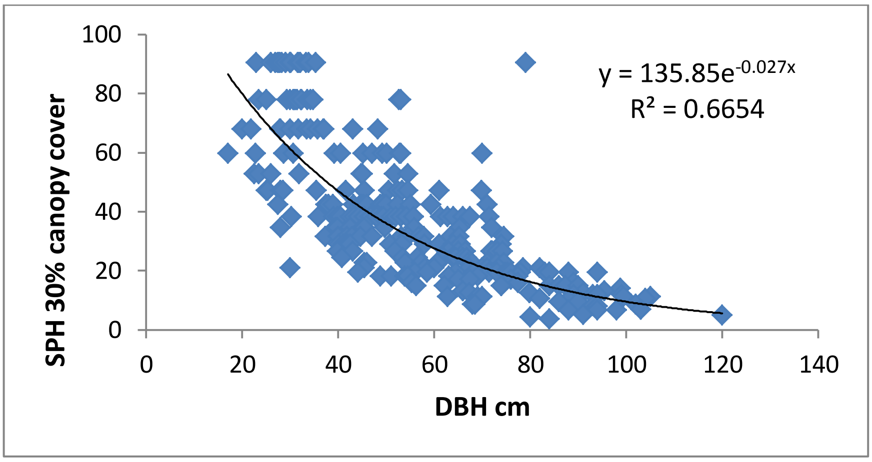

Figure 5. Poplar planting density required to achieve 30% canopy cover at differing DBH (N= 282).

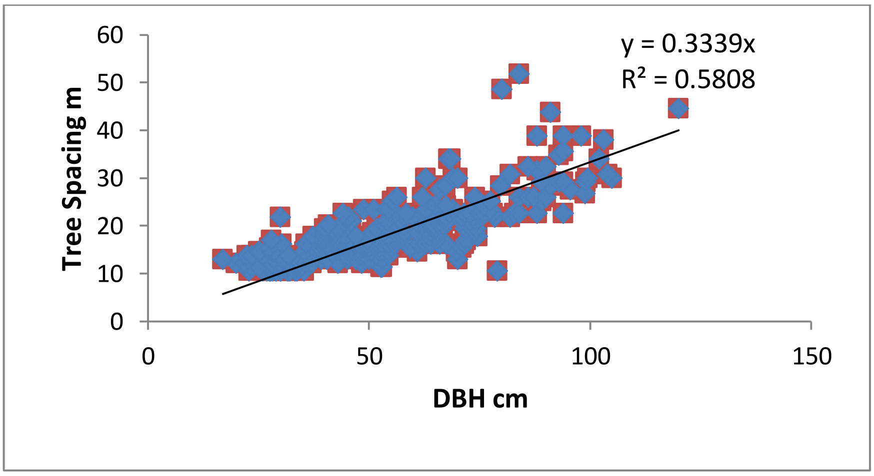

Figure 6. Poplar tree spacing required to achieve 30% canopy cover at differing DBH (N=282).

It is apparent that poplars (Figures 5, 6) show greater variation in canopy cover compared with willows (Figures 7, 8). The poplar data excludes the very narrow form Lombardy poplars which distorted the graphs and reduced the R^2 values. There are many more poplar species and hybrids present in the landscape than there are willow species and hybrids. Almost all willows on farms are *Salix matsudana* or *Salix matsudana x alba* which have a relatively uniform shape. The earlier poplar clones released for on-farm planting were developed for the plantation timber industry in Europe. As it turned out their branching pattern produced a wide canopy which is favourable for gaining carbon credits but not so favourable for pasture production. New Zealand bred clones were selected for narrower canopy to improve light to pasture and as a consequence more trees per hectare will be required to achieve 30% canopy cover (http://www.poplarandwillow.org.nz/pages/breeding-&-research/breeding/strategy/).

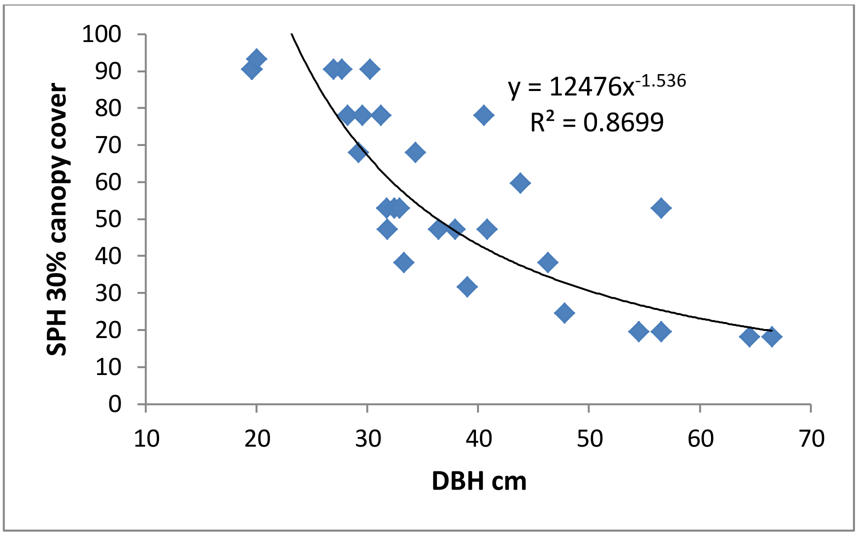

Figure 7. Willow planting density required to achieve 30% canopy cover at differing DBH (N= 60).

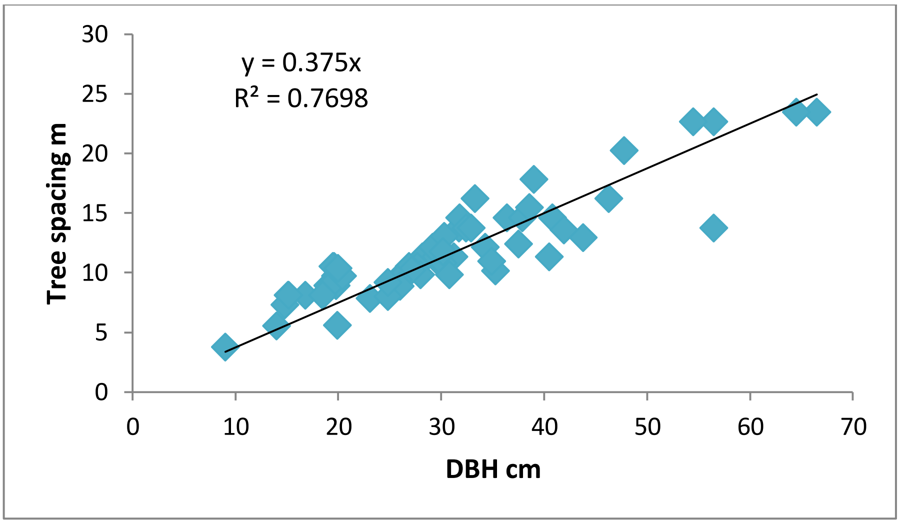

Figure 8. Willow tree spacing required to achieve 30% canopy cover at differing DBH (N= 60).

Two examples are given in Figure 9, for ‘Toa’ and ‘Tasman’ poplar clones.

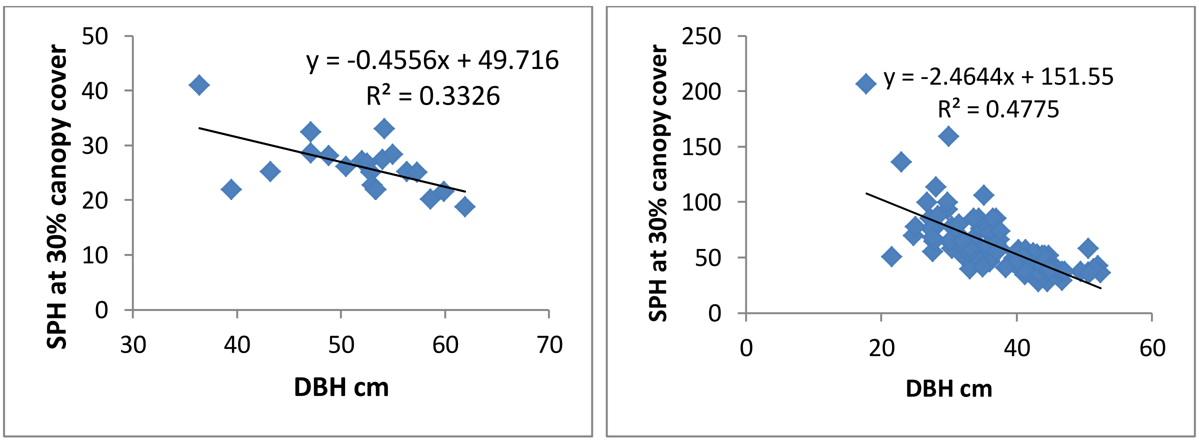

Figure 9. Planting density required to achieve 30% canopy cover at differing DBH for ‘Toa’ (left) and ‘Tasman’ (right) hybrid poplar clones.

While the function differs, a stocking rate of 31 stems per hectare (SPH) for 'Toa' at DBH of 40 cm will achieve 30% canopy cover, whereas for 'Tasman' a stocking rate of 53 SPH is required at that DBH.

Decisions cannot be made on the basis of canopy cover alone since different clones have different attributes, including soil moisture requirement, drought and wind tolerance, and bark hardiness. However, where some extra trees are needed to create corridors between already existing plantings and reach the minimum of one hectare in area of planted trees then selection of a poplar clone with a wider canopy to fill the space could be appropriate.

Soil conservation or carbon credits?

Those land owners who have practised a policy of increasing the resilience of their farm to rain storm events through progressive planting of trees are now in a position to take advantage of the ETS. It is clear from the issues raised in this paper regarding the time taken for a tree to develop the root system required to stabilise slopes to the degree that they will show minimal slippage following a heavy rain event or prolonged rainfall, that to achieve the requirements of the ETS for carbon credits will take considerable time (upwards of 12 years).

To achieve 30 % canopy cover trees will need to be planted to a greater density than would be required to stabilise the soil at maturity. Assuming all poplar root systems extend out beyond 10 m, regardless of the clone, then at maturity (DBH >30 cm) 30-40 SPH would be sufficient to stabilise a slope, whereas, using the information from Figure 8, 36 SPH (Toa) or 78 SPH (Tasman) would be required to achieve 30% canopy cover. It would seem that the greater priority is soil stabilisation, then pasture production and finally carbon credits. However, there is the opportunity to carry out strategic planting to connect current conservation plantings so they become eligible for carbon credits. Pruning lower branches of conservation poplar trees will increase light to pasture while at the same time having little effect on canopy cover, or capacity to stabilise the soil.

References

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