The effect of crown pruning on poplar-pasture-soil interactions

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Executive Summary

- An estimated 3% of rainfall was intercepted and evaporated from the canopies of the 6 year old 'Veronese' hybrid trees (*Populus deltoides* x *P. nigra*) during the period Sept 01 – Apr 02. Stemflow during this period represented only 0.78% of total rainfall.

- Soil water content at the shallowest depth (0-200 mm) in the tree sites did not differ greatly from water content in the open sites. However, deeper in the soil profile (200-800 mm) soil water content was significantly lower under trees. At sites such as 'Ballantrae' soil water content will only limit pasture growth during periods of drought.

- Runoff volumes were highly variable and no significant differences are likely to be detected between the tree and open treatments.

- The average water use of two selected trees at the site was 78 L/day (dbh = 13.0 cm) and 110 L/day (dbh = 16.8 cm). The latter water use equates to 1.7 mm/day. Form pruning to 5 m reduced the daily water use by 30%.

- The changes in the understorey light environment and resulting changes in pasture production following pruning will be reported in 2003.

Objective

Several studies have already been conducted on pastoral farms to determine the effect of intermediate-and mature-aged widely-spaced poplars on the surrounding environment (e.g. Douglas *et al*., 2001; Gilchrist, 1993; Guevara-Escobar, 1997). However as was noted at a recent workshop (Westbroke, 2002), few experiments have addressed the impact of silviculture regimes on the soil conservation role of the trees. Of particular interest is the trade-off involved in form-pruning to maximise understorey pasture production and create a usable butt-log, whilst still maintaining the ability of the tree to improve soil strength. Therefore the ongoing objective of this study is to determine the impact of pruning young poplar trees on the surrounding environment, particularly those physical changes likely to affect soil conservation, such as:

- the site water balance – soil water content, rainfall, throughfall, stemflow, runoff, and uptake by the trees and pasture.
- the site light environment – pasture production and evapotranspiration rates.
- root mass and distribution.

This report outlines some of the preliminary findings from this project, which is being carried out at AgResearch Ballantrae Research Station near Woodville. Most of this report outlines data and results before pruning. However, this study is expected to continue until Autumn 2003 when the environmental changes in response to tree pruning will be reported on.

Methods

Site description

A south-east facing hill slope at AgResearch Ballantrae was planted with 3 m 'Veronese' poplar (*Populus deltoides x P. nigra*) poles in 1995. The trees are spaced 7-8 m apart in a grid pattern (160 stems per hectare), approximately following the contours along the hill face. In winter 2001 the trees had a mean height of 8.9 m and a mean diameter at breast height (dbh) of 13.2 cm. The resident pasture was grazed by sheep every 3-4 weeks during summer. The climate is temperate with mean daily air temperature ranging from 6.8 ^{o}C in July (winter) to 18.1 ^{o}C in February (summer). Annual rainfall at the site during 2001 was 1250 mm.

In November 2000 two uniform sites were selected at opposite ends of the paddock, one for a pruning treatment (P) and another for an unpruned control treatment (UP) – the "do nothing" option. A third "open" pasture treatment (O) was created by clearing several trees from the middle of the site. The trees in the P treatment were pruned on March 6th 2002. During pruning, the diameters of the branches at the point of removal (usually at the intersection between the branch and the central leader) were recorded. The approximate leaf area removed from each tree was calculated using the diameters recorded, and data from a complete tree harvest in February 2002 that had established a relationship between branch diameter and leaf area (Figure 1).

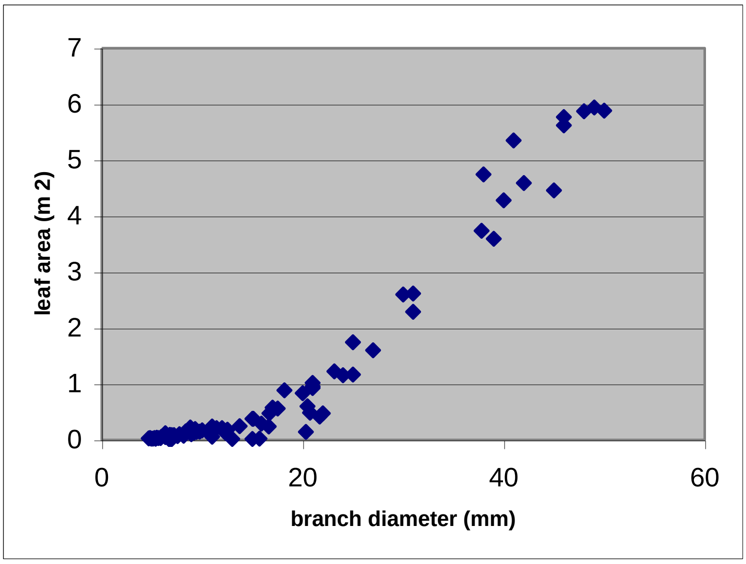

Figure 1. Leaf area relationship with branch diameter for Veronese poplar in February 2002.

A. Quantifying the Water Balance

Soil water content

Soil water content was measured fortnightly in summer and every 3-4 weeks in winter around a selected tree in each of the P and UP treatments. Time Domain Reflectometry (TDR) probes were installed at 2, 4 and 5 m distances in four directions from the tree trunks, and soil water content was measured at 4 depths (0-200 mm, 200-400 mm, 400-600 mm and 600-800 mm) at each of these locations (Figure 2). Additional probes were buried at the same depths at four randomly chosen sites in the open treatment.

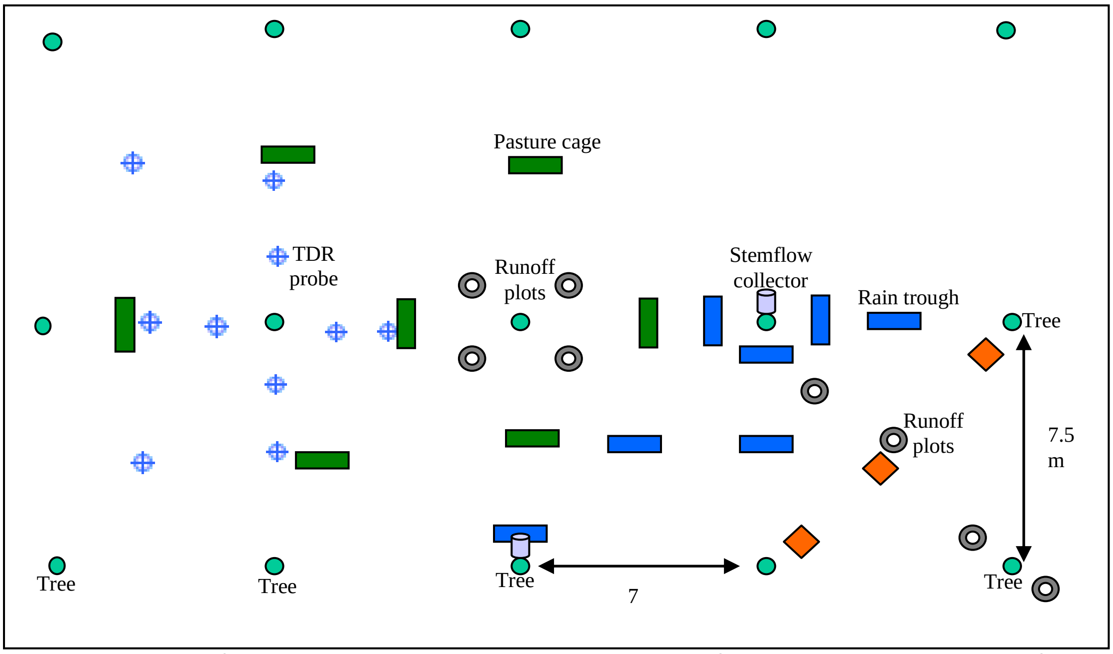

Figure 2. Location of the instrumentation measuring components of the site water balance. This figure shows the layout for the P treatment, a similar arrangement was set up in the UP treatment.

Rainfall and Stemflow

Rainfall was collected and measured using troughs constructed of spouting, with outflows collecting the water through a tube into sealed 20 L containers. The troughs were fastened onto posts 1 m above the ground to avoid interference by stock. Seven troughs were strategically arranged within each tree treatment (P and UP) to best measure the effect of the trees at different locations within the grid (Figure 2). Four troughs were randomly placed within the open treatment for comparison. Approximately every fortnight or following significant rainfall events, the volume of rain collected in each trough was measured using measuring cylinders. The trough collection areas ranged from 0.110 - 0.115 m^2, and rainfall volumes were corrected for this difference. A meteorological station also logged rainfall (to an accuracy of 0.2 mm) in the open treatment.

Stemflow (water that flows down the tree trunks during rainfall events) was measured on four trees, two in each of the P and UP treatments. Flexible plastic tubes (11 mm diameter) were wrapped in a slight downwards spiral around the tree trunks, for one complete 360° rotation. The tubes were fixed to the tree using a non-toxic silicon-based sealant, and grooves were cut in the plastic to allow "stemflow" water to enter the tube and flow downwards into a sealed 50 L container at the base of the trees. Stemflow volumes were measured and recorded following rainfall, however during periods of very heavy rain the containers sometimes overflowed and measurements were lost.

Surface runoff

Surface runoff was measured in two ways. The first approach was to construct enclosed 0.5 m^2 square plots, angled so that one corner of the plot pointed directly downhill. The upper sides of these plots were marked by folded sheet metal inserted in the ground to a depth of 50 cm, in order to prevent surface runoff flowing onto the plot from further uphill. The downslope sides of the plots were dug out, and folded sheet metal was used to create a "lip", flush with the soil surface. Runoff from these plots ran over this "lip" into covered spouting, which was placed in the dug out trench immediately flush with the edge of the plot. The spouting was joined and sealed at right angles to create an L shape, and 11 mm tubing was inserted into a hole drilled in the corner. The runoff was collected through this tubing into a sealed 50 L container. Three of these runoff plots were installed in each treatment. The second type of plots were constructed from 30 cm diameter hard PVC drainage pipe sawn into 30 cm lengths. 21 lengths of this pipe (8 in the P and UP treatments and 5 in the open) were installed vertically in the ground to a soil depth of 25 cm. 11 mm tubing was inserted into a hole drilled flush with the soil surface on the downslope of the pipe, and the runoff was collected through this tubing into 10 L containers.

Poplar water-use

In early February 2002 instrumentation to measure tree sap flow was installed in one tree in each of the P and UP treatments. The rate of tree water uptake was determined by measuring the time taken for a pulse of heat to travel between two sensors in the tree xylem. This equipment was connected to a Campbell data logger and continuous measurements of tree water use were recorded until late March, thereby enabling measurement of the change in water use following pruning of one of the trees on March 6.

B. The Light Environment and Pasture Production

Light environment

Canopy photos were taken in December 2001, January 2002 and April 2002 using a Nikon SLR camera mounted on a tripod 30 cm above the ground. A hemispherical lens was attached to the camera to capture the entire 360° above-ground image. The photos were taken from the same fixed positions as the pasture cages (see below) and will be scanned and analysed using the Gap Light Analyzer (GLA) software. This software uses the photos to predict the quantities of direct and diffuse radiation at these locations. By comparing photos taken in December 2001 and April 2002 the reduction in canopy light interception due to pruning will be quantified.

Pasture production

Pasture production was measured monthly from March 2001 to March 2002 using a standard pre-trimming technique involving 0.2 m^2 grazing exclusion cages (Radcliffe, 1974). The cages were located at seven midpoints between 12 trees in both the P and UP treatments (Figure 2), and at 4 locations in the open site. At each harvest, herbage in the caged areas of all plots was cut with electric shears to a residual sward height of 1-2 cm. The dry weights of the herbage cut from each cage were determined following drying for 12 hrs at 80^{o}C.

C. Root Biomass and Distribution

An exploratory excavation of the structural roots of a then 5-year old tree was conducted at Ballantrae in 2000. Excavation was done by digging around the base of the tree, and systematically tracing all roots with a diameter greater than 2 mm. The distribution of the roots was mapped and their approximate depths noted.

Results and Discussion

A. Quantifying the Water Balance

Soil water content

Figure 3 shows the mean soil water content in the P and UP treatments combined, at different depths and distances from the two trees. Mean water content at four locations within the open site is also shown. At the shallowest depth seasonal soil moisture levels ranged from 20-50% of total soil volume but large differences between the tree and open sites were not apparent. However, at depths of 200-400, 400-600 and 600-800 mm, summer and autumn soil moisture levels within the tree sites were consistently lower than those in the open site. For example, on April 3 2002, mean soil water content at 2 m from the trees was 36.1%, 34.7% and 38.1% at depths of 200-400, 400-600 and 600-800 mm respectively. Mean water content measured on the same day and at the same depths in the open sites was 40.3%, 39.7% and 42.2%. The difference between tree and open sites at soil depths of 600-800 mm was maintained throughout the entire year, however at the other depths moisture levels become similar during the winter.

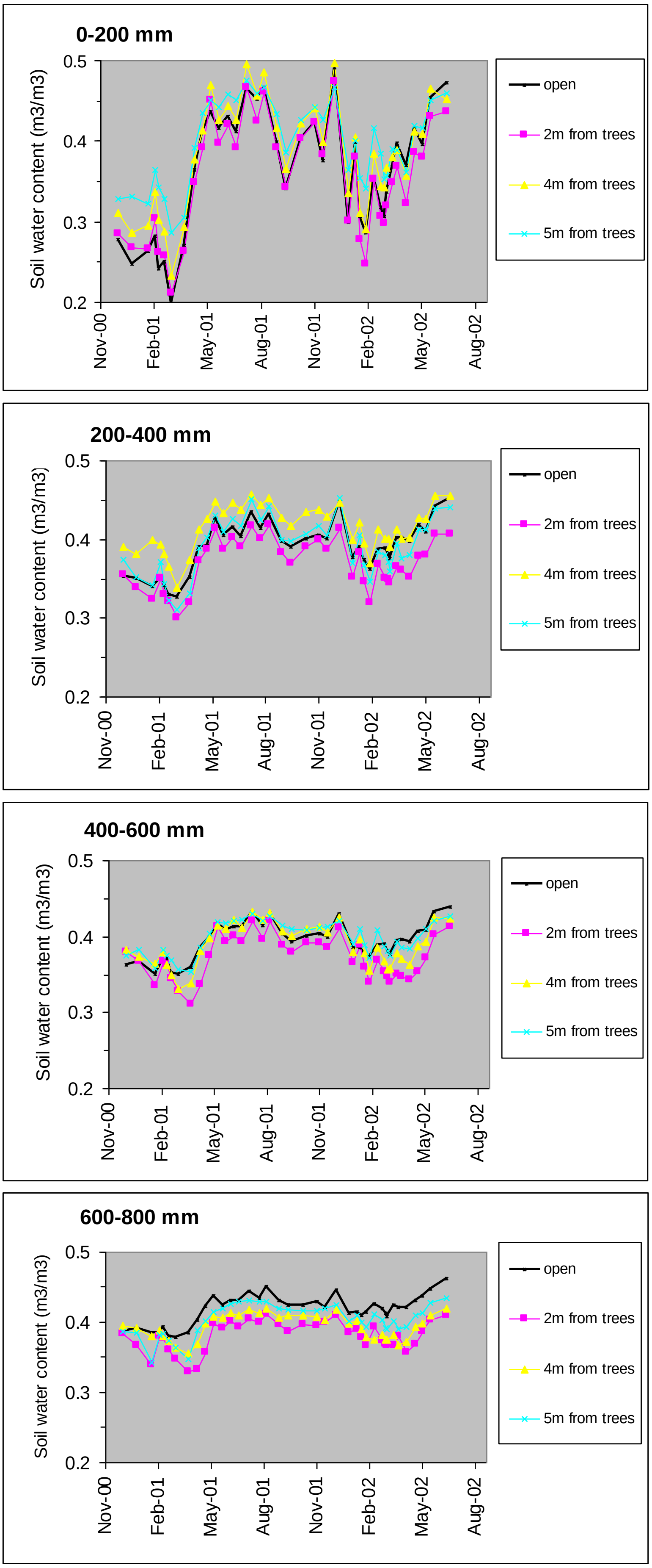

Figure 3. Mean soil water content at depths of 0-200mm, 200-400mm, 400-600mm and 600-800mm. Mean water content at distances of 2, 4 and 5 m from the trees (P and UP treatments combined), and in the open site are plotted.

There are two factors that probably contribute to the reduction in water content around the trees. The first is obviously water uptake by the poplar roots. Previous soil coring experiments have shown that poplar roots at this site have extended to at least a depth of 1.2 m, and that root concentration is highest close to the tree trunk. We also know that the roots can extend out >8m from the base of the tree (see page 56), however the graphs here indicate that the density of absorbing roots at 5m is only half of that at 2m (seen from the difference in the 2m and 5m lines from the open line). These results are therefore consistent with the findings from our root distribution studies. The second factor that may also contribute to lowering soil water content is that the tree roots are likely to alter physical characteristics of the soil such as density and porosity. We expect that increases in soil porosity would improve the soil drainage and therefore lower water retention, and this possibility will be investigated during summer 2002/03.

Rainfall and Stemflow

The troughs in the P and UP sites were located in order to best measure the effect of the trees at different locations within the plantations. Total rainfall from Sept 01- Apr 02 in each tree site location and the percentage of these with respect to the open site are shown in Table 1.

Table 1. Average rainfall totals from Sept 01- Apr 02 in each tree site location and the percentage of these rainfalls compared to the open site rainfall of 800mm.

	P site			**UP site**		
Trough (s) location	n	rainfall (mm)	% of open rainfall	n	rainfall (mm)	% of open rainfall
1m from tree (All 4 directions)	4	721	90.1	4	721	90.1
4m from tree (N/S direction)	1	759	94.9	1	767	96.0
4m from tree (E/W direction)	1	762	95.3	1	769	96.1
5m from tree (Centre of grid layout)	1	835	104.4	1	844	105.6

During the poplar growing season, the average rainfall volumes from both groups of four troughs located 1 m from the trees was only 90% of the 800 mm recorded in the open site (table 1). The total rainfall volumes 4 m from the tree in North/South and East/West directions were also affected by canopy interception, however rainfall in the centre of the four trees was actually higher than in the open by 4-6%. By combining these averages we can estimate the overall effect of trees on rainfall at this site. For the purposes of this calculation we assumed that each trough location in Table 1 represents a good approximation of the rainfall over a quarter of the tree site. For example, rainfall in the the 8 troughs sited 1 m on the North, South, East and West of the trees is a good estimate of the average rainfall in the area up to 2 m from a tree trunk in all directions. On the basis of these assumptions, the percentages of rainfall collected 1 m from the ground in the P and UP sites when compared with the open sites, are 96.2% and 97.0% respectively.

The "missing " 3-4% of rainfall is attributed to both interception and evaporation from the tree canopy, and movement of water down the tree trunk (stemflow). Investigation of the latter was carried out on four trees in winter and six trees in summer. During winter a greater proportion of rain flowed down the trunk (Figure 4), presumably due to less interception and resistance by leaves. A simple linear trendline fitted to the data shows that average stemflow (L) on these trees in winter was 1.08 x rainfall (mm). In summer this almost halved to 0.62 x rainfall (mm) for the same four trees, which were slightly larger in diameter by this time. When this is expressed as a percentage of the rainfall during the period Sept 01-Apr 02 measured above, we calculate that 0.78% of the "missing" 3-4% is stemflow. We assume that the remaining rainfall evaporates from the tree canopy before reaching the understorey. Two of the trees were in the P treatment however no effect of pruning was detected.

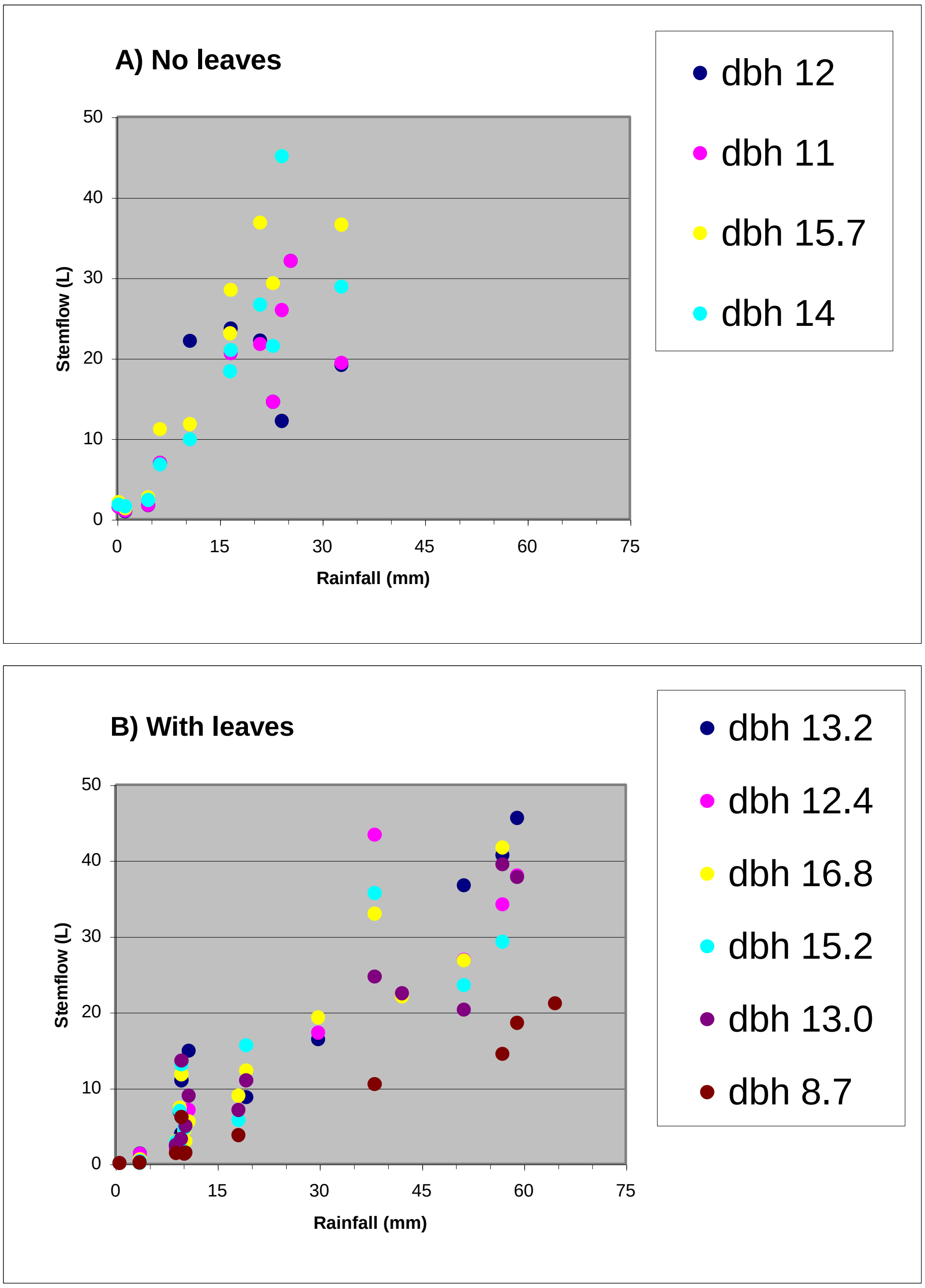

Figure 4. Stemflow according to rainfall volume, during the period when trees have leaves (A) and no leaves (B).

While measurable, the low percentages of stemflow and evaporation indicate that other factors such as tree water uptake have a more important impact on the site water balance in young widely-spaced plantations.

Runoff

The trees may reduce mean surface runoff following medium to heavy rain events as seen in Figure 5 below, however this effect is unlikely to be statistically significant as the data is extremely variable. We would expect that in summer the land under the trees has a greater capacity to take up precipitation because of the lower soil moisture levels, however in very dry soil this can even have the opposite effect, due to the soil hardening and becoming less penetrable. In widely-spaced plantations of young trees it is likely that topographical features such as catchment size, gullies and hillocks will have a more dominant effect on total runoff volumes.

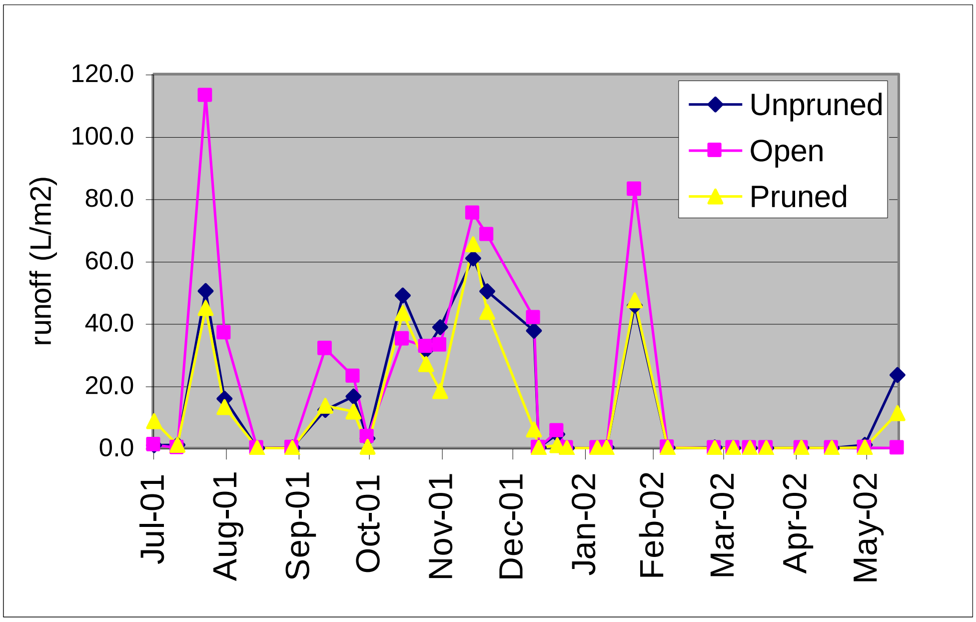

Figure 5. Average surface runoff (L/m2) measured on 8 (P and UP treatments) or 4 (Open treatment) circular plots from July 01-May 02.

Tree water use and pruning

The trees in the P treatment are bigger than those in the UP treatment, and the trees selected for water-use measurements in these blocks had a dbh of 16.8 cm and 13.0 cm respectively. Consequently the water use of "Tree 2" was an average of 110 L/day, 20-30 L/day higher than Tree 1 prior to pruning (Figure 6). This water use is equivalent to 1.7 mm/day at 8 m x 8 m spacings. Guevara-Escobar et al (2000) measured the water-use of mature *Populus deltoides* trees and showed that an average of 188 L/day was transpired, which equated to 0.92 mm/day at 37 stems per hectare.

Leaf area directly relates to the amount of water the tree uses, and form pruning to 5 m on March 6 reduced the water use of Tree 2 by approximately 30%. From the relationships we have established between branch diameter and leaf area (figure 1) and whorl number and leaf area (data not shown) we estimated that approximately 40% of the tree leaf area was removed.

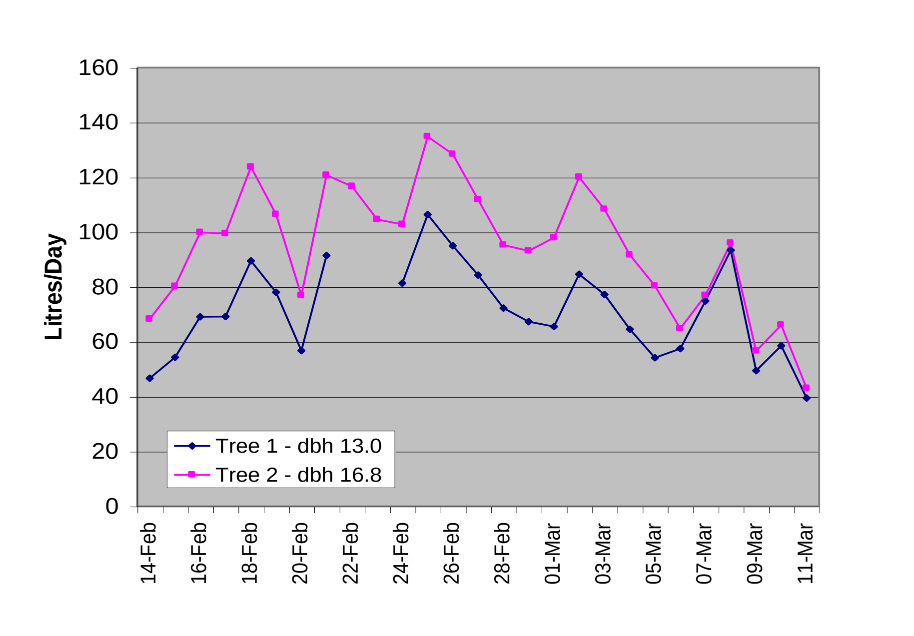

Figure 6. Daily water use of two trees during February and March. Tree 1 was in the UP treatment, while Tree 2 was in the P treatment and was pruned on March 6th.

B. The Light Environment and Pasture Production

We are not yet able to report on the changes in the light environment or the changes in pasture production following pruning. However visual observations are that the understorey of the pruned site is considerably lighter following pruning. We expect to see an increase in pasture production in summer 2002-03 relative to the previous year. Figure 7 will be our baseline data with which we can compare production following the pruning which occurred at the end of this period.

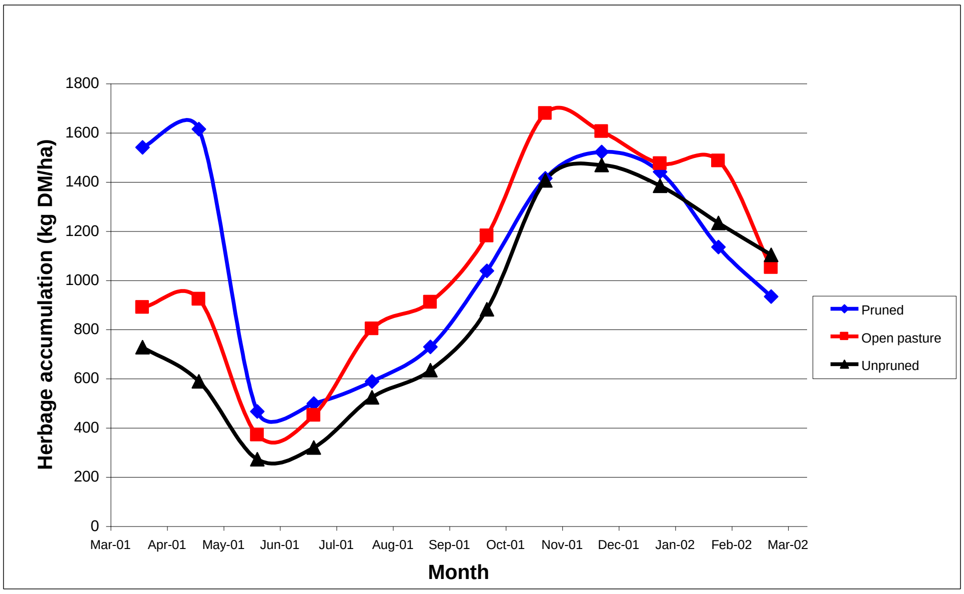

Figure 7. Pasture production during 2001/02 according to treatment (n=4 (Open) and n=7 (Pruned and Un-pruned)).

C. **Root Biomass and Distribution**

In an excavation in 2000 we found that the lateral roots of the then 5-year old trees extended in excess of 8 m from the pole. The laterals typically stayed within 50 cm of the ground surface, however occasionally turned sharply downwards to become sinkers, presumably at the end of a growth season. Most vertical roots were within 1 m from the base of the pole. The distribution of roots was roughly symmetrical - mostly concentrated on the NE and SW sides of the tree – with no obvious effect of hill slope. Root biomass according to diameter classes and distance from the tree is shown in Table 2. The trees have increased in average dbh by about 4 cm since 2000 and a corresponding increase in root growth would have occurred, therefore the current root distribution will be much higher than the figures below.

Further work is required to verify these trends and to establish relationships between root biomass, root length, and aboveground measurements such as tree dbh and height. However, in the future, techniques such as mechanical excavation or hydraulic sluicing may be employed to speed up the process.

	Distance from tree in all directions (metres)						
Root diameter (mm)	0-0.5	0.5-1	1-2	2-4	4-6	6-8	8+
2-5	27	3	1	32	22	21	3
5-10	24	15	55	103	57	14	
10-20	79	45	23	3			
20-40	38						

Table 2. Dry root biomass (g) according to distance from the tree trunk and diameter class.

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