PFR SPTS No. 17742

Early root development in 'Tangoio' tree willow planted as poles

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April 2019

1 SUMMARY

Several studies have reported on root development of poplars of various ages growing on pastoral slopes but little is known of root development of willows grown on pastoral hillslopes. This report presents new information about root development in willow trees grown from poles.

The root systems of 20 *Salix matsudana* × *alba* ‘Tangoio’ willows aged 2–6 years were partially excavated to a depth of 0.5 m and out to 1 m distance from the trunk. The willows were growing in a clay loam soil on pastoral hillslopes in Wairarapa. Roots were excavated from a lower quadrant only, the quadrant selected for uniform slope, and were excavated in two sections: from the trunk to 0.5 m, and from 0.5 to 1 m. The root systems of two trees aged 4 and 6 years were excavated beyond 1 m and to 0.5 m depth till the roots terminated. Deeper roots were not excavated.

Root length (RL) and root mass (RM) increased from year 2 to year 6, as did RM density and RL density beyond 0.5 m radius. RL distribution across diameter classes was similar to previous studies, with root <2 mm diameter being 86–94% of RL, of which root <1 mm diameter accounted for 77–85% of RL.

Roots of willows aged 4 and 6 years extended 5.1 m and 5.3 m, respectively, whereas few 2-year-old trees had roots extending beyond 1 m of the trunk.

Based on this study and a separate study of root development in *Populus xeuramericana* ‘Veronese’ poplar aged 1–3 years in clay loam in Wairarapa, the pattern of root development in ‘Tangoio’ tree willow and ‘Veronese’ poplar are considered to be similar, particularly regarding root extension, with ‘Tangoio’ having a lower rate of root development.

The zone of effective soil stabilisation of a single willow both extends and strengthens with time as roots lengthen and increase diameter. Our data suggest that for ‘Tangoio’ willow trees spaced 10 m apart, the root systems of separate trees are just starting to share soil space by age 6 years in clay loam soil, with the intermeshing of adjoining root systems further enhancing soil stabilisation.

Key words Willow, root system, pastoral, slope, clay loam

2 INTRODUCTION

Until now, root studies of conservation trees in hill country have focused on poplars. Both poplars and willows are planted for soil conservation, with willows being ~40% of poles planted annually in pastoral hill country. While earlier willow plantings were concentrated in gullies, current planting of willows is also extending across hill slopes. In this study we report on root growth in *Salix matsudana* × *alba* 'Tangoio' trees aged 2, 4 and 6 years (Figure 1), planted on hill slopes on a single property in Wairarapa in 2013, 2015 and 2017. The soil type is clay loam, slope varied between 15° and 24°, and aspect varied between northeast and west.

3 METHODS

The root systems of 20 *Salix matsudana* × *alba* 'Tangoio' willows aged 2–6 years were partially excavated to a depth of 0.5 m and out to 1 m distance from the trunk. The partial excavation per tree allowed for more trees to be sampled for the same effort. Four trees aged 2 years, eight trees aged 4 and eight trees aged 6 years were excavated. Roots were excavated from a lower quadrant only, the quadrant selected for uniform slope, and were excavated in two sections: from the trunk to 0.5 m, and from 0.5 to 1 m. Roots found in each section were kept separate. Roots were sorted into various diameter classes (0–1 mm, 1–2 mm, 2–5 mm, 5–10 mm, 10–20 mm, 20–40 mm and >40 mm) in the field and root length (RL) was measured. A sample of excavated roots from four of the trees was retained and sorted into diameter classes in the laboratory, RL measured, the roots dried at 70°C for 5 days and root dry weights (RM) recorded. Conversion factors were calculated for each root diameter class and used to determine the RM of the roots that remained in the field.

Figure 1. 'Tangoio' willow aged 6 years (left), 4 years (centre) and 2 years (right).

Two trees (aged 4 and 6 years) were selected for excavation of the entire root system to 0.5 m depth and in a single quadrant as above, i.e. beyond 1 m from the tree trunk. Excavated roots were sorted into diameter classes. RL was measured in the field for each diameter class excluding 0–1 mm. Samples of roots in each diameter class were retrieved for measuring root dry mass and calculating ratios of RL to RM. All excavated roots of these two trees were retrieved and RL for roots 0–1 mm were measured. The RL ratio of roots 0–1 mm diameter to roots 1–2 mm diameter was calculated and subsequently used to estimate RL of 0–1 mm diameter roots for all 20 trees.

RL density and RM density were modelled for radial distance beyond 1 m by extrapolating the density decline from 0–0.5 m to 0.5–1 m for radial distances 1–1.5 m and beyond.

The excavated roots were treated as representing one-quarter of the roots present to 1 m radial distance from the tree. Support for this assumption is from a 3-year study of early root development in poplars growing on slopes where the root parameters were similar upslope and downslope, although root amounts in each quadrant were not recorded. Data are presented for the quadrant only, not for the whole tree.

4 RESULTS AND DISCUSSION

RL and RM distribution across diameter classes (Figures 2 and 3) was similar to previous studies (Phillips et al., 2014), with fine root <1 mm diameter accounting for 77–85% of RL, and fine root <2 mm diameter being 86–94% of RL within the excavated radius of 1 m and depth of 0.5 m. Mean RL for roots >1 mm diameter was 6.1 m, 11.7 m and 10.9 m per quadrant for 2, 4 and 6 year trees respectively. Mean RM for all roots was 21.2 g, 117.6 g and 184.3 g per quadrant for 2, 4 and 6 year trees respectively.

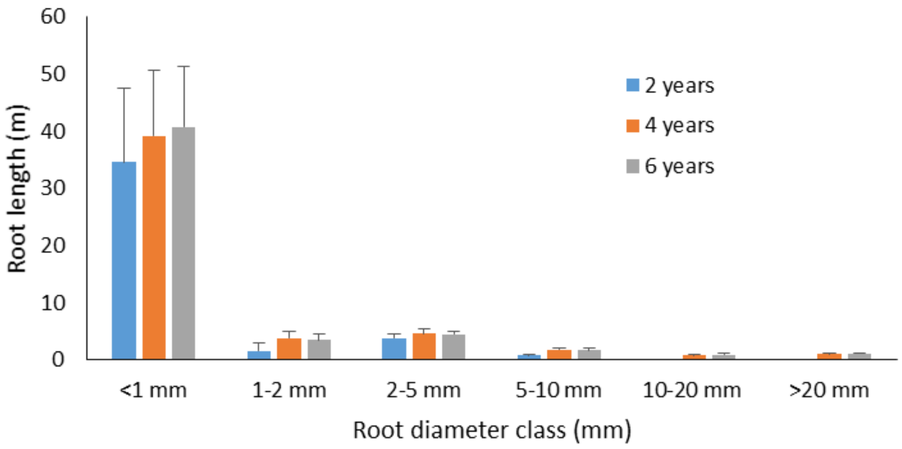

Figure 2. Mean root length to 0.5 m depth and 1 m distance from the tree, separated by diameter class for 'Tangoio' willows aged 2, 4 and 6 years. Error bars = standard error of the means.

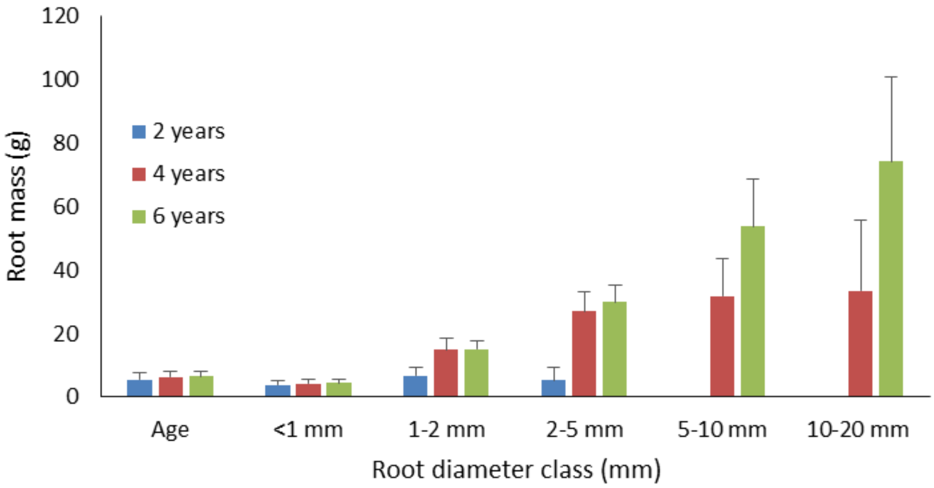

Figure 3. Mean root mass to 0.5 m depth and 1 m distance from the tree, separated by diameter class for 'Tangoio' willows aged 2, 4 and 6 years. Error bars = standard error of the means.

For the single trees aged 4 and 6 years for which all roots to 0.5 m depth were excavated, RL beyond 1 m was 70% and 82%, respectively, of total RL. The equivalent % RL for willow aged

2 years was estimated at <10%. The longest roots excavated extended 5.2 m and 5.3 m, respectively, for trees aged 4 and 6 years.

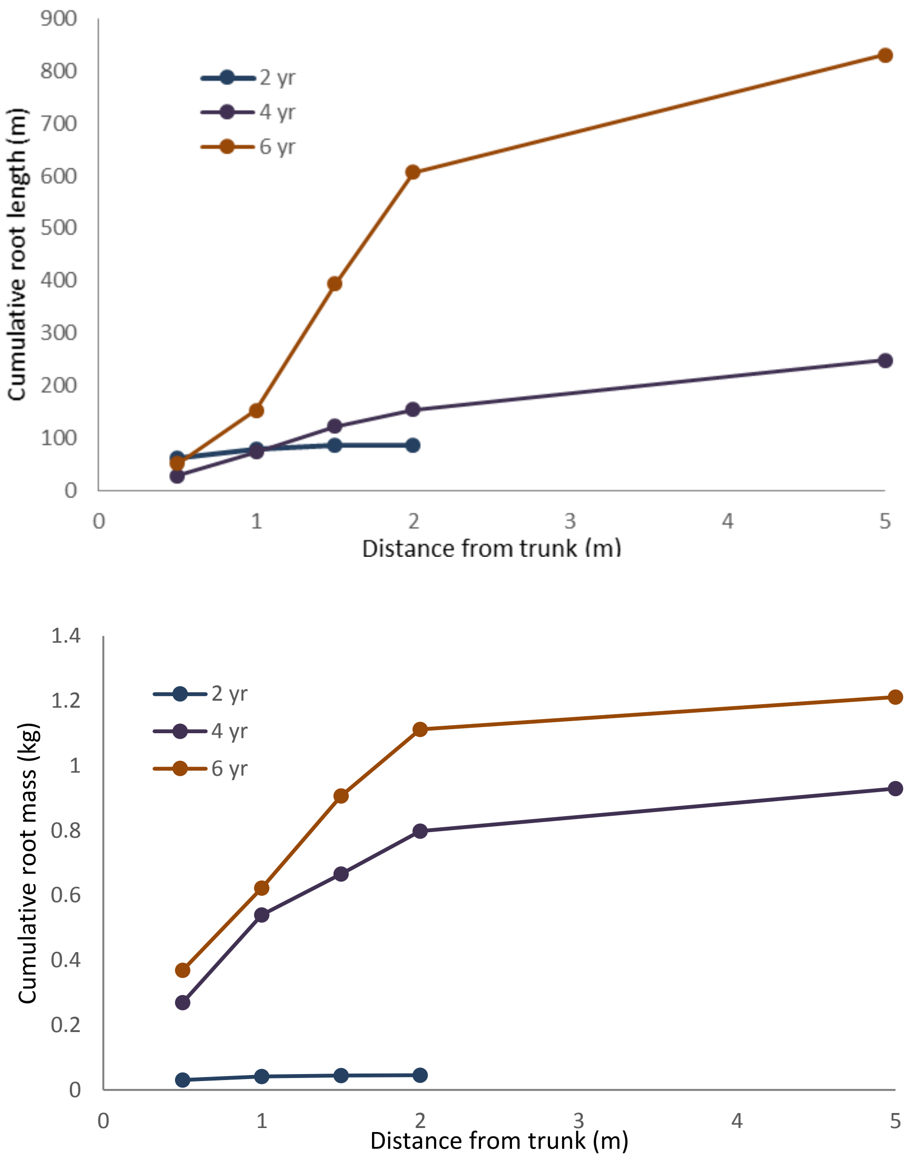

Figure 4. Cumulative root length (upper) and root mass (lower) changes with age for 'Tangoio' willow aged 2, 4 and 6 years. Data are from single trees at each age.

RL and RM increase rapidly once the pole gets established (Figure 4). The increase in above-ground growth with age (Figure 1) appeared to correlate well with root development, and vice versa. No above-ground data were collected.

RL density increases further from the trunk as the trees age, i.e. more root is present further away from the trunk. The zone of effective soil stabilisation is extending further from the tree. Likewise, at the same time roots are thickening, not only are they extending, they are also strengthening to better resist soil movement.

Our data suggest that for ‘Tangoio’ willow trees spaced 10 m apart, the root systems of separate trees are likely to be intersecting by age 6 years in clay loam soil. The intermeshing of adjoining tree-root systems is significant in resisting slope erosion (Ahn et al., 2007; Douglas et al. 2010; McIvor et al. 2011; Schwarz et al. 2010; Stokes et al. 2009).

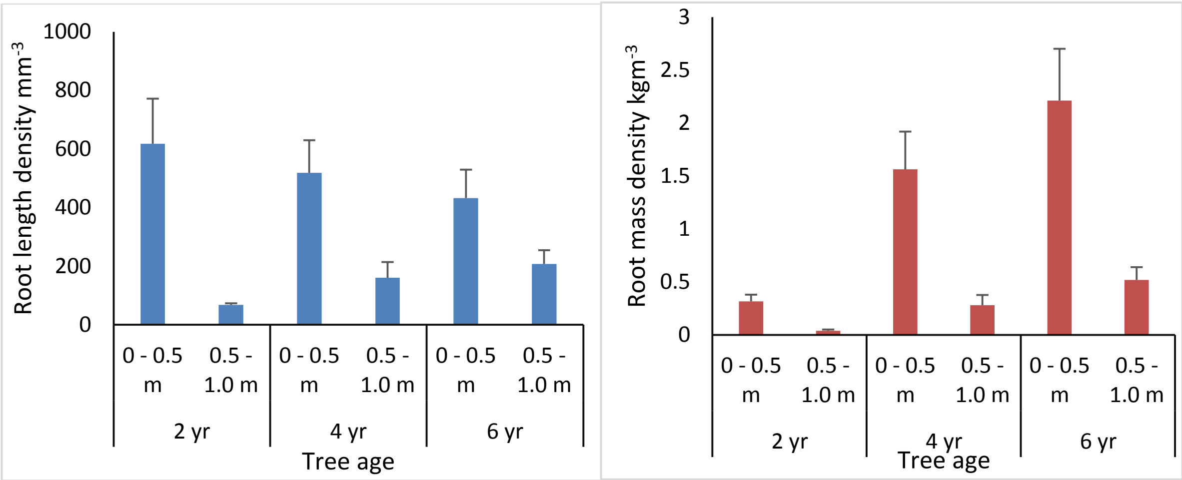

Figure 5. Changes in root length density (left) and root mass density (right) at different distances from the trunk for ‘Tangoio’ willows aged 2, 4 and 6 years. Error bars = standard error of the means.

Root extension increased with age, as did RL density (mm^{-3}) and RM density (kgm^{-3}) (Figures 5 and 6). This result shows that the spaces between roots are increasingly being populated with new roots (Figure 7), increasing contact of the root-soil interface, and strengthening resistance to soil movement.

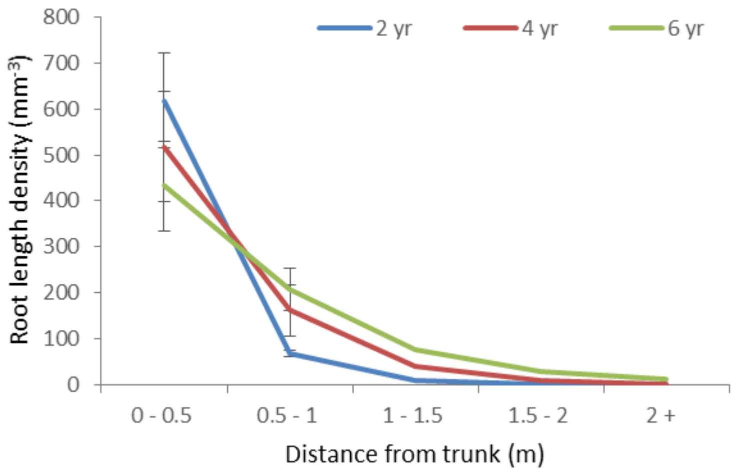

Figure 6. Mean root length density to 0.5 m depth and at varying distance from the tree, for ‘Tangoio’ willows aged 2, 4 and 6 years. Error bars = standard error of the means. Values beyond 1 m are modelled.

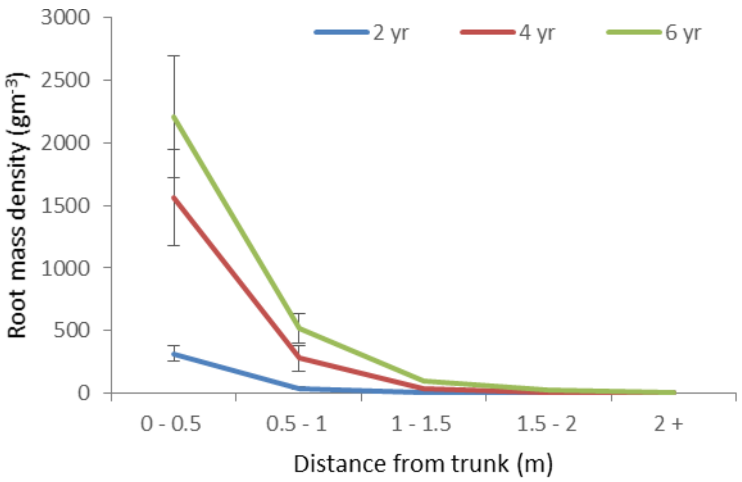

Figure 7. Mean root mass density to 0.5 m depth and at varying distance from the tree, for 'Tangoio' willows aged 2, 4 and 6 years. Error bars = standard error of the means. Values beyond 1 m are modelled.

Root extension is radial, vertical and oblique. As roots branch they can and do grow in independent directions. Sinker roots take a vertical path, radial roots may continue in the same direction, or grow upslope or downslope (Figure 8), or upwards and downwards obliquely.

This study did not capture information on roots initiating below 0.5 m depth. The greatest diameter roots observed were growing downwards close to the trunk, with the rest of the root present below 0.5 m depth.

Previous studies have shown that poplar roots will grow laterally for long distances, and at depths below 0.5 m. 'Tangoio' willow grown from a pole in an irrigated sandy loam soil had a root spread of 11 m and a RL of 525 m for roots >1 mm diameter after one growing season (Phillips et al. 2014) and roots had penetrated to 1 m depth. Rates of both willow and poplar root penetration were reduced through more compact soils and through subsoil compared with upper soil layers (McIvor et al. 2014). Since poles are planted to 0.7–0.8 m depth, roots initiated from the bottom of the pole are already close to 1 m in depth.

At age 2 years, roots terminated within 1 m of the trunk. The longest root found for a 4-year-old tree was 5.1 m (Figure 8). By age 6 years, shallower roots of 'Tangoio' willow reached to 5.3 m and there were more long roots than for trees aged 4 years (Figure 8).

5 COMPARISON WITH POPLAR ROOT GROWTH

The percentage of RM found in the top 0.5 m of soil for 'Veronese' poplar aged 1–3 years, measured between 2014 and 2016 on a hillslope in a Wairarapa clay loam was 79–94% (McIvor et al. unpubl.). Mean RL for roots >1 mm diameter was 2.2 m, 7.5 m and 39.7 m per lower quadrant after 1, 2 and 3 years, respectively. For the willows in this study, equivalent measures were 6.1 m, 11.7 m and 10.9 m after 2, 4 and 6 years, respectively. At 3 years, poplar roots in clay loam soil had not extended beyond 2 m. At 4 years, willow roots were as far as 5 m from the trunk. As far as these comparisons are valid, willow and poplar root development are comparable, although the rate of willow root development being possibly less. 'Veronese' poplar and 'Tangoio' willow poles grown in an irrigated sandy loam soil had RL for roots of diameter >1 mm of 255 m and 525m, respectively (Phillips et al., 2014). Early root development in sandy loam soil was greater in 'Tangoio' willow than in 'Veronese' poplar. 'Kawa' poplar and 'Hiwinui' willow grown in the same experiment had RL of 379 m and 533 m. This supports root development being greater in young tree willows than in young poplars. Whether this continues as the trees mature is uncertain.

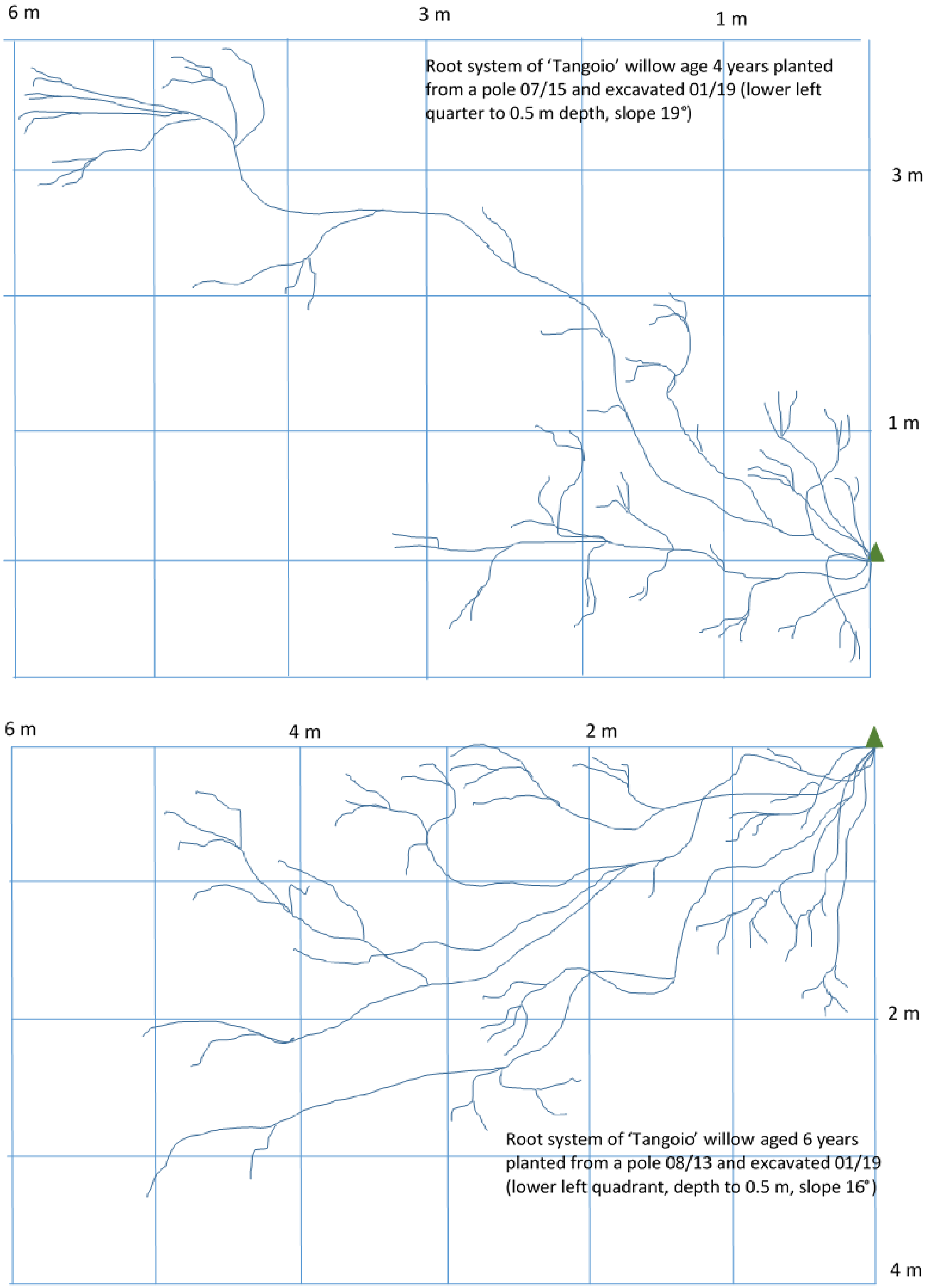

Figure 8. Radial root growth in 'Tangoio' willow aged 4 and 6 years (data to 0.5 m depth and mapped for one quadrant only).

Canopy growth is a proxy of above-ground growth of ‘Tangoio’ willow. These data suggest that root growth can be inferred from canopy growth. This being the case, conservation willows can be visually scanned across a hillslope and the below-ground environment can be better understood from the extent of the canopy, as being more or less favourable for root growth. However, the direction of root extension cannot be inferred from the canopy size or shape since the roots do not follow a linear path.

6 CONCLUSIONS

The zone of effective soil stabilisation of a single willow both extends and strengthens with time, as roots lengthen and increase in diameter. Root presence was largely within 1 m of the trunk up to age 2 years but at ages 4 and 6 years roots had extended to 5 m. Our data suggest that for ‘Tangoio’ willow trees growing in clay loam soil and spaced 10 m apart the root systems of separate trees are sharing soil space by age 6 years. Root development in ‘Tangoio’ willow is comparable with root development of ‘Veronese’ poplar as found in other studies.

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Confidential report for:
TBA

PUBLICATION DATA

McIvor I, Jones T, Ward R. April 2019. Early root development in 'Tangoio' tree willow planted as poles. A Plant and Food Research report prepared for: TBA. Milestone No. 75025. Contract No. TBA. Job code: P/442060/10. SPTS No. 17742.

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