SOIL QUALITY IN PASTORAL HILL COUNTRY AS INFLUENCED BY THE PRESENCE OF WILLOW (*SALIX MATSUDANA* × *ALBA*) TREES

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Abstract
The benefits of conservation poplars and willows for the stabilization of soil on New Zealand hill country are well recognised, but not so well understood is how these trees may influence soil quality. We tested the hypothesis that soil conservation trees growing on pastoral hill slopes would increase soil organic matter and change the physical properties that are influenced by organic matter (e.g., bulk density (BD)).

The study was conducted in December 2010 on hill country sheep and beef farmland approximately 10 km SSW of Waipukurau in Central Hawke's Bay. Transects from three 13-year-old willow trees were marked out in an area where there were no other trees found within 10 m. Intact soil samples (0-15 and 15-30 cm layers) were taken at 1, 2, 3, 4, 5, 7 and 10 m from each tree. Total carbon (C) and nitrogen (N) determined by (LECO Truspec C/N analyser). Labile C and N: extracted using hot (80ºC) water; C and N in extracts determined using a Shimadzu total organic carbon (TOC) analyser (5000A). Bulk density: estimated from the soil mass in the 0-15 and 15-30 cm cores.

There was a significant increase in bulk density with increasing distance from the base of the trees. There was also a significant decrease in organic matter with distance from the trees. On a logarithmic scale, HWC to 15 cm depth showed a significant linear trend with distance from the trees. At 15-30 cm soil depth, there was no biologically significant trend in HWC, despite the mean values at 1 m to 4 m from the tree being higher than values at greater distances. Hot water-extractable N in the 0-15 cm layer decreased significantly with distance from the trees but in the 15-30 cm layer, there was no statistically significant trend. The findings support the hypothesis that conservation trees on pastoral slopes can confer soil quality benefits by increasing soil organic matter over distances up to 10 m from the trees. It would be useful to repeat this study for conservation trees differing widely in age to better understand the rate of organic matter accumulation under trees.

Introduction
New Zealand's pastoral farming landscape, particularly in hill country, where spaced trees frequently have two or more functions such as erosion control, shade and shelter for livestock, supplementary fodder for livestock and birds, nutrient and C storage and nutrient recycling will continue to be an integral part of agroforestry (Benavides et al., 2009). Tree litter may improve soil fertility not only through the release of nutrients in the soil by mineralization but also by adding soil organic matter (Gupta et al., 2009) There is strong potential for agroforestry systems in sequestering C in above-ground vegetation and in

below-ground organic matter. This capture of carbon may help offset CO2 emissions from other sources (Albrecht and Kandji, 2003).

The benefits of conservation poplars and willows for the stabilization of topsoils on New Zealand hill country are well recognised but not so well understood is how these trees may influence soil quality. This study tested the hypothesis that soil conservation trees growing on pastoral hill slopes would increase soil organic matter and change physical properties that are influenced by organic matter (e.g., bulk density, BD).

Methods

Study location

The study was conducted in December 2010 on hill country sheep and beef farmland approximately 10 km SSW of Waipukurau in the Central Hawke's Bay (Figure 1).

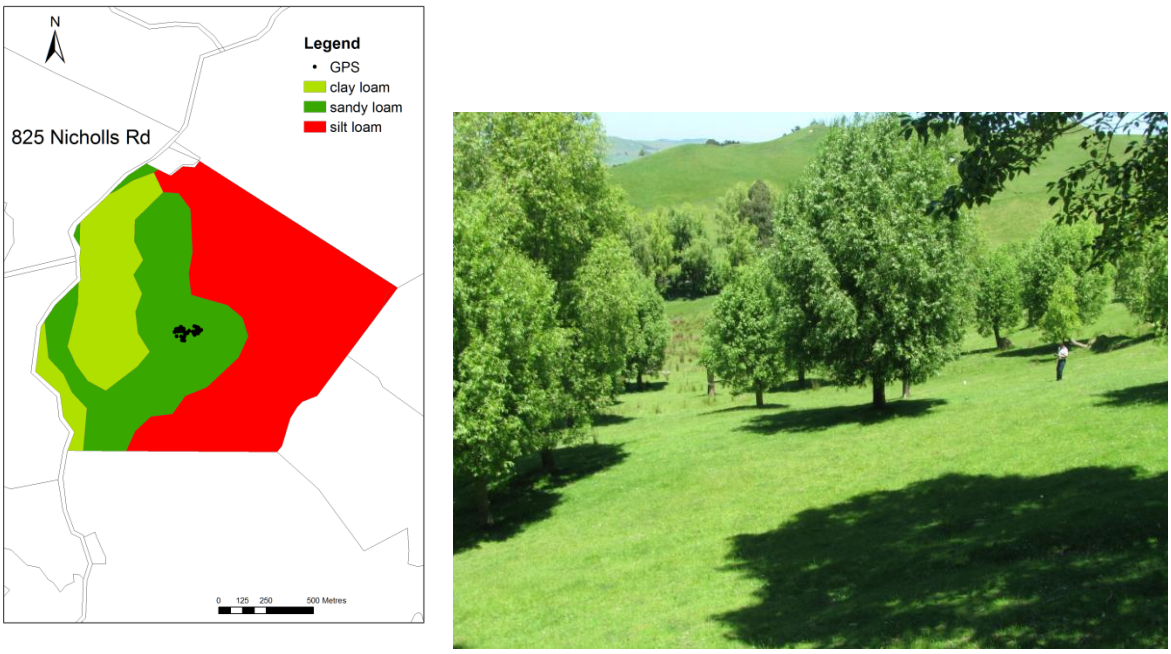


Figure 1. Pastoral hill country farm site, central Hawke's Bay, New Zealand.

Sampling methods

Transects from three willow trees were marked out in an area where no other trees were within 10 m of the transect and intact soil samples (0-15 and 15-30 cm layers) taken at 1, 2, 3, 4, 5, 7 and 10 m from each tree.

Analytical methods

Total C and N: determined by automated combustion (LECO Truspec C/N analyser).

Labile C and N: extracted using hot (80^{o}C) water; C and N in extracts determined using Shimadzu total organic carbon (TOC) analyser model 5000A analyser.

Bulk density: estimated from the soil mass in the 0-15 and 15-30 cm cores.

Statistical analysis
Data were analysed using analysis of variance (ANOVA), comparing differences in the means for distance from tree and depth.

Results and discussion

Willow tree dimensions
The 13 year old willow trees from which transects were sampled varied little in diameter at breast height (DBH); DBH ranged from 36.0±5.7 to 38.8±5.7 cm and mean annual growth was 1.4±0.9 to 1.8±1.9 cm.

Bulk density (BD)
There was a significant increase (0.011 g/cm^3 (SE=0.004) per metre) in bulk density (BD) with increasing distance from the base of the trees (Figure 2). Root density was higher close to the trunk of willow trees. Roots may lift the soil as they grow, resulting in lower BD where root density is high. Bulk density has been shown to decrease as organic matter content increases when variation in other factors such as structure and texture are minimal and BD is often higher in areas visited more regularly by stock such as feeding and camping areas (Mulholland and Fullen, 1991). The dip in BD at 4 m from the base of the tree may be due to this zone being less desirable for stock camping, offering less shade hours during the day, while still being within the influence of the root zone. Alternatively, it could be due to increased root density near the canopy drip line associated with higher moisture after rain events.

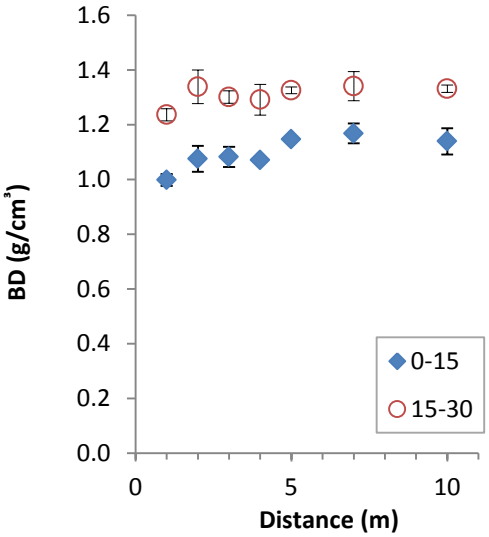
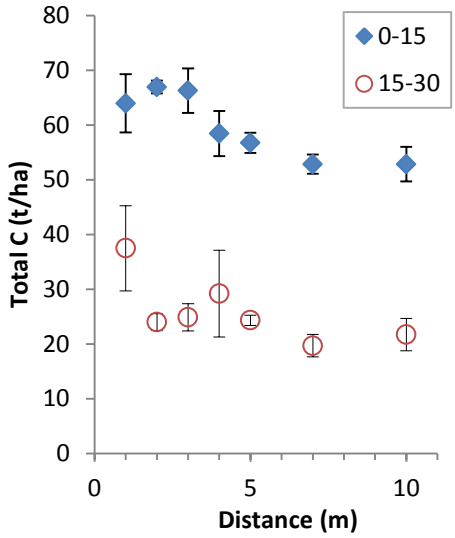


Figure 2.Change in soil bulk density (0-15 cm and 15 - 30 cm depths) with distance from the willow trees.

Total C and N
There was a significant decrease in organic matter with distance from the trees, i.e., total C and N in the top 30 cm decreased by about 1.51 t/ha (SE=0.37) and 0.136 t/ha (SE=0.027) per metre, respectively (Figure 3a & b). This spatial trend is likely due to greater addition of leaf litter, and root residues (Wilson, 2002) in the vicinity of the trees. The influence of stock camping cannot be discounted as it is likely to result in greater manure deposition near the trees. However Wilson, 2002, found consistently lower organic content under trees in stock paddocks than non stocked paddocks. Young, 1989, have indicated that soil organic matter is

increased in pastoral situations by the presence of trees. Results reported here support the hypothesis that there may be significant potential to increase carbon sequestration in soils through the use of trees on pastoral land.

a)



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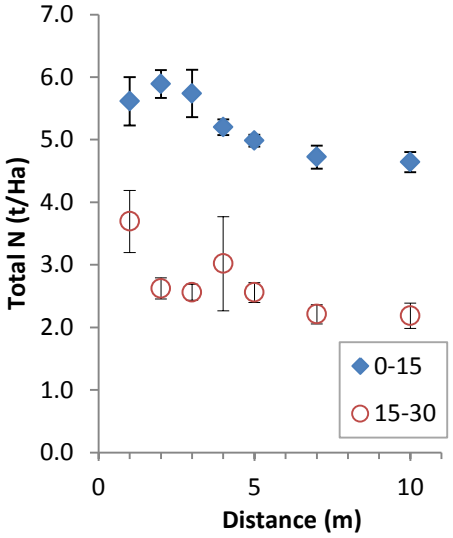


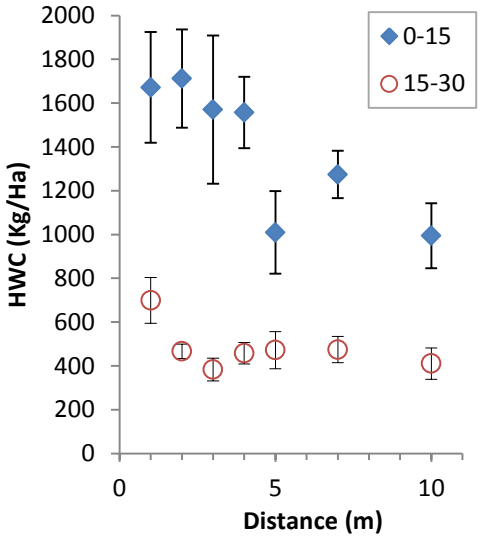
Figure 3. a) Soil total C and b) N (0-15 and 15 - 30 cm depths), with distance from the willow trees.

Hot water-extractable C (HWC) and N (HWN)

Hot water extraction is a sensitive method for determining subtle changes in organic carbon and nitrogen within a soil ecosystem and changes in the total organic C in soils were also reflected in the HWC pools (Ghani et al., 2003). On a logarithmic scale, HWC (Figure 4a) to 15 cm depth showed a significant linear trend with distance from the trees; which translated to a drop of 6% (SE=1.7%) per metre. At 15-30 cm soil depth there is no significant trend in HWC, despite the mean values at 1 m to 4 m from the tree being higher than values at greater distances. Hot water-extractable N (Figure 4b) in the 0-15 cm layer decreased significantly

[by 6% (SE=1.5%) per metre] with distance from the trees but, in the 15-30 cm layer, there was no significant trend. Bambrick et al., 2010, reported a nil increase in soil organic carbon (SOC) in a 4 year old tree-based intercropping system and a 12% increase in a 21 year old tree-based intercropping system compared with a conventional agroecosystem. McIvor et al., 2009 found that for conservation poplars growing on pastoral hillslopes root production was low at 5 and 7 years but had increased exponentially by year 11. This rate of production is likely to be reflected in a corresponding increase in contribution to HWC and HWN.

a)



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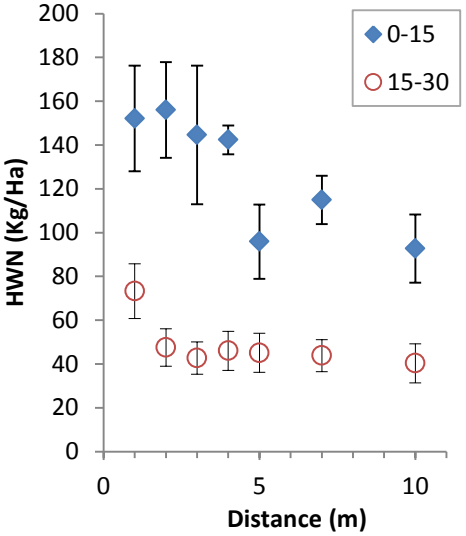

Figure 4. a) Changes in hot water-extractable C (HWC) and b) N (HWN) (0-15 and 15 - 30 cm depths) with distance from the willow trees.

Conclusions

These findings support the hypothesis that conservation trees on pastoral slopes can confer soil quality benefits by increasing organic matter in the soil over distances up to 10 m from the trees. The labile or active component of soil organic matter was also higher near the trees. Soil physical condition (bulk density) was significantly better close to the trees where organic matter levels were higher.

It would be useful to repeat this study for conservation trees differing widely in age to better understand the rate of organic matter accumulation under trees.

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