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# KĀNUKA AS A SILVOPASTORAL TREE FOR LOW PRODUCING HILL COUNTRY

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There has been much research on southern Europe and Californian oak (*Quercus* spp.) silvopastoral 'tree-pasture' systems. These systems have been shown to conserve water and build soil resources compared to open pasture in many situations (Howlett et al., 2011; Joffre & Rambal, 1993; Marañón et al., 2009). This can result in more pasture production under their canopies compared to open pasture (Callaway et al., 1991; Frost & McDougald, 1989, 1989; Moreno, 2008). For example, Moreno (2008) found 19% more pasture production under holm oak (Quercus ilex L.) compared to open pasture in three Spanish silvopastoral sites. Peri (2005) also found more pasture production under (No*thofagus antarctica* (G. Forst.) Oerst.) forests of southern Patagonia, Argentina, in severely water stressed sites.

There have been many studies that have measured the impact of silvopastoral trees in New Zealand hill country (Benavides et al., 2009; Kemp et al., 2018). These studies have focused on poplar (*Populus* spp.) and radiata pine (*Pinus radiata* D. Don). Nevertheless, no published study has found more pasture production under fully mature silvopastoral trees in New Zealand. These negative pasture production outcomes are most likely because poplar and radiata pine are fast growing and large, and so add too much competition for resources in the silvopastoral environment. Another tree that grows readily in hill country is kānuka (*Kunzea* spp.) (Bergin et al., 1993; Spiekermann et al., 2021). This tree has contrasting bio-physical attributes to poplar and radiata pine, which means a silvopastoral system with kānuka add less competition to the pastoral environment and result in improved pasture production outcomes under their canopies (see Mackay-Smith et al., 2021). If a silvopastoral tree can be found that improves pasture production under its canopy in New Zealand hill country, silvopastoralism has the potential to overcome key trade-offs between production and environmental outcomes, and form multifunctional landscapes in New Zealand.

The research objectives were to 1) measure pasture production under isolated silvopastoral kānuka trees and in open pasture, 2) measure how the growth of pasture species functional groups is impacted by isolated kānuka trees and 3) discriminate which variables contribute to pasture production and pasture species functional group differences between positions.

## *Methods*

The study was undertaken for two years from December 2019 to December 2021 on two New Zealand hill country commercial sheep and beef farms. One site was in the Wairarapa region ~10 km North of Martinborough, and the other was in Hawkes Bay ~20 km South of Waipukurau. Within each paddock at each site, individual *Kunzea robusta* de Lange et Toelken (kānuka) trees grew throughout the paddocks at ~10 trees $ha^{-1}$ to ~2000 trees $ha^{-1}$. Pasture dry matter production, pasture functional group composition, soil fertility, soil physical characteristics, soil moisture and light interception were quantified directly under the canopy of 9 tree replicates (4 at Wairarapa and 5 at Hawkes Bay) and in equivalent open pasture positions (in terms of slope and slope position) (Figure 1). All measurement positions were on north facing slopes and were between 20° and 25°.

Green dry matter production was measured using the pre-trimmed exclusion technique (Radcliffe et al., 1968). After an initial pre-trim to 1 cm, pasture was harvested after a ~ 2 month regrowth period. Both sites were harvested on consecutive days. Cages were rotated between three locations after each regrowth period, for each position. After sampling, pasture was separated into pasture species functional groups following the groups defined by López et al. (2006), and dead matter, then oven dried at 70 °C. Pasture green dry matter production, individual pasture species functional groups and dead matter were analysed.

**Figure 1.** The kānuka trees evaluated in the study. The left photo shows the kānuka trees at the Wairarapa site, and the right photo shows the kānuka trees at the Hawkes Bay site. Both photographs were taken by the lead author.

Ten soil cores were taken between 0 cm and 7.5 cm in December 2019 and December 2021. Soil was analysed for pH, Olsen-phosphorus, total-nitrogen, soil organic matter, sulphate-sulphur, cation exchange capacity, magnesium, potassium, calcium and sodium. Bulk density, particle density, porosity, macroporosity (pore sizes > 54 μm) (Dörner et al., 2015) and available water capacity (pore sizes between 54 μm and 0.2 μm) (Dörner et al., 2015) were also measured.

Soil moisture was measured continuously using time domain reflectometry soil moisture sensors (Campbell Scientific CS616; sensor length 30 cm) at each position at two depths (0 – 30 cm and 30 – 60 cm). Photosynthetically active radiation (PAR) measurements were taken 30 times each season three times in the day at solar noon, solar noon – 2.5 hours, solar noon + 2.5 hours between December 2020 and December 2021. After the 30 PAR measurements at a position, one measurement was taken from the equivalent open pasture position. Light interception (%) was calculated by subtracting each kānuka pasture position from the open pasture measurement.

### *Results and implications*

This study found 107.9% more green dry matter pasture production in kānuka pasture positions compared to open pasture positions. There was significantly more dead matter in open pasture. Measurements were similar at both sites in both years, so these results indicate that in certain situations, kānuka as a silvopastoral tree can positively influence pasture production outcomes in New Zealand hill country. Light interception was 67.2% and 51.2% at the Wairarapa and Hawkes Bay site, respectively. Olsen-phosphorus, organic matter, total-nitrogen, cation exchange capacity, potassium, porosity and macroporisty were all significantly greater under the trees. Soil moisture was similar under and away from the trees at both depths (year-round and just in summer). The variation in green dry matter production was best explained by olsen-phosphorus, porosity, potassium and cation exchange capacity. The improvements in organic matter and soil structure under the trees suggests that the trees facilitated a substantial change to the agricultural environment. This was hypothesised to be because of livestock nutrient transfer, in addition to litterfall adding organic matter to the soil in kānuka pasture.

*Lolium perenne* L., *Dactylis glomerata* L., and high fertility annual grasses (*Bromus hordeaceus* L. and *Critesion murinum* L. Á.Löve) increased with the improved agricultural environment under the kānuka trees over the two years at both sites. *Agrostis capillaris* L., medium fertility species (*Anthoxanthum odoratum* L.) and low fertility tolerant grasses (*Rytidosperma* spp. and *Vulpia bromoides* (L.) Gray) were most strongly associated with the poorer soil conditions of open pasture. This study found trees can promote the growth of fast-growing species under silvopastoral trees, which resulted in greater green dry matter pasture production under the trees.

The greater pasture production and the growth of more productive pasture species shows that kānuka could potentially be used to increase the productivity of open pasture areas in New Zealand hill country. As no previous published study has found increased pasture production under silvopastoral trees in New Zealand hill country, these results open the door for continued work into silvopastoral trees that have facilitating impacts on pasture production outcomes. Because kānuka will most likely provide many other important environment and cultural benefits to hill country (see Mackay-Smith et al., 2021), a kānuka silvopastoral system has the potential to form diverse, resilient, and productive rural landscapes in New Zealand.

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