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**ASPECTS OF A POPLAR-PASTURE SYSTEM
RELATED TO PASTURE PRODUCTION IN
NEW ZEALAND**

**A thesis presented in partial fulfilment of the requirements for
the degree of Doctor of Philosophy in Plant Science
at Massey University, New Zealand**

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ABSTRACT

Widely spaced poplars (*Populus deltoides*, <100 stems/ha) are the best technology to control soil erosion over 3.7×10^6 ha in New Zealand on sedimentary hill soils. To date, the effects of poplars on water, soil and pasture relations are poorly studied. This thesis compared traditional stable open pasture (OP) and widely spaced poplars (5-40 years old) and its grass/legume understorey (PP) based on rainfall partitioning, soil and pasture characteristics.

It was concluded that mature PP (>29 years old and 37-40 stems/ha) used more water during November (18 days) as evapotranspiration (*ET*, 2.7-3.0 mm d⁻¹) than the OP (2.2 mm d⁻¹). Canopy rainfall interception (1.37 mm d⁻¹) was more important than tree transpiration (0.92 mm d⁻¹) or understorey *ET* (0.4-0.6 mm d⁻¹). Despite the differences in water partitioning, soil water (θ) in the PP was similar or higher than in the OP.

The mature PP had lower topsoil θ (0-150 mm) than the OP during 1996 (37 and 43 %v/v, respectively). PP topsoil was drier in January, May and June, but θ was similar to the OP in other months of 1996. During dry weather (1997), θ in the topsoil was higher in the PP than in the OP. Variation in θ around the trees was significant but small in magnitude. PP soil temperature was lower than in OP particularly during summer.

Soil pH was higher (0.5-1.2 units) in the PP as were exchangeable cations. Poplar leaf litter decomposition along with poplar N nutrition, reduced soil water leaching and legume N-fixation, all contributed to higher soil pH. Using the legume dry matter (DM) as a proxy of N-fixation, the PP fixed 54% of that in the OP. With the exception of lower total N in the PP, little differences were found in organic C, total N, P or S, or soil P or S fertility, hydraulic conductivity, porosity and water aggregate stability between the OP and PP. Earthworm populations were similar or lower in the PP.

Pasture DM accumulation in the mature PP was 60% (6.2 t ha⁻¹ yr⁻¹) of that in OP as the poplar canopy (70% canopy closure ratio) allowed only 20% of the photosynthetically active radiation in the OP to reach the understorey. The legume proportion was similar between the OP and PP, although actual yield was lower in the PP. The PP area had slightly lower grass percentage at the expense of higher comminuted tree debris material. OP forage generally had higher feed value in terms of crude protein, metabolisable energy and *in vitro* DM digestibility.

With the exception of higher soil pH, no difference in other soil or understorey characteristics was found between the OP and PP planted with young poplars.

The understorey could take advantage of improved soil water and pH conditions if silvicultural management reduced the shading effect from poplars without impairing soil conservation. Canopy and understorey management options to increase/better utilise pasture DM are discussed.

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GLOSSARY AND ABBREVIATIONS¹

A.C.: after Christ.

ADF: acid detergent fibre.

Agroforestry: refers to silvopastoral systems oriented to timber production or soil erosion control. In New Zealand, sometimes used synonymously with "farm forestry" (i.e., forestry as practised by farmers) or even "any forestry on ex-farm sites". Some users apply the term only to low tree stockings. Here taken to mean the intensive management of trees, pasture, and livestock on the same area of land at the same time. As a stand matures, the pasture and livestock component may become of lesser importance.

Amenity value: means those natural or physical qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes.

ANOVA: analysis of variance.

ASC: anion storage capacity.

asl: above sea level.

B.C.: before Christ.

BD: soil bulk density.

Biofuel: plant biomass that is used to generate energy or synthetic petrol (gasoline) not derived from petroleum.

Blanket forestry: plantation of whole farm with a single species, in New Zealand this means *Pinus radiata*.

Block forestry: as in blanket forestry, but only selected areas of the farm are planted.

Breast height: in New Zealand, breast height is taken to be 1.4 m above ground on the uphill side of the tree. Many other countries, including Australia, use 1.3 m.

Canopy: the part of a tree consisting of branches and foliage. "Canopy closure" is the stand age when the branches touch, or nearly so, thereby restricting light to the forest floor.

CCR: canopy closure ratio, the percentage of canopy closure.

Clearfelling: the felling of all trees in a stand at the same time.

Clearwood: wood free of knots achieved through pruning. Tree trunks do not stretch as they grow: they expand only in diameter at any given point. They grow from cells formed just under the bark, so that branch stubs remain at their original height and become "buried" in later knot-free wood.

Compression wood: abnormal wood formed on the lower side of branches and leaning stems. Generally confers undesirable wood properties.

CP: crude protein.

D: drainage.

DAP: diammonium phosphate.

DBH: tree diameter at breast height over bark.

¹ Parameter identifiers of equations are not listed because same descriptors were used in the linear and nonlinear models for consistency.

DM: dry matter.

D&D: diagnosis and design.

Earthflow: see mass movement.

ET: evapotranspiration.

Externality: positive or negative unpriced values resulting from human activity.

Greywacke: a sedimentary rock composed of silt or sand particles which have been hardened and cemented.

Gorse: *Ulex europaeus*, one of the most important bushy weeds in New Zealand.

Gullying: erosion of soil or rock by ephemeral streams downcutting through hillslopes, after heavy rain.

Hardwood: the common name for angiosperms, or broadleaves. The expression "hardwood" does not necessarily indicate that the wood is hard (e.g., balsa is a hardwood). Natural tropical forests are predominantly hardwoods, although hardwoods also occur in temperate countries. Temperate hardwoods are often deciduous. Hardwoods usually have flowers and broad leaves.

Heartwood: inner wood (inside the sapwood) no longer transporting water or storing food. It is normally darker in colour than sapwood due to deposits of complex organic compounds.

Hill country: all the land with slopes between 12 and 28°, but low relief; typically 100 to 300 metres' difference in elevation. Valley bottoms are usually narrow.

I: tree canopy interception.

IVD: *in vitro* digestibility.

Lopping: cutting one or more branches of a woody plant.

LSD: least significant difference.

LW: live weight.

Mass movement: erosion of soil or rock by gravity-induced collapse. Usually triggered by groundwater pressure after heavy rain, but can also have other causes, notably streams undercutting the base of a slope, or earthquakes. Movement can either be rapid and near-instantaneous (landslides, avalanches, debris flows) or slow and intermittent (earthflows, slumps).

ME: Metabolisable energy.

Mudstone: a sedimentary rock composed of silt and clay particles, compacted and weakly cemented together by a small quantity of lime.

na: not analysed.

NDF: neutral detergent fibre.

NIRS: near infrared reflectance spectroscopy.

Open pasture: hill country pastureland where trees were far away.

OP: see open pasture.

P: rainfall precipitation.

PA: pasture accumulation.

PAR: photosynthetically active radiation.

Poplar-pasture: hill country pastureland widely spaced planted with poplars.

PP: see poplar-pasture.

Possum: synonym of opossum, a small tree-dwelling marsupial feeding mainly on plant material. Endangered in Australia, but along with rabbits it is the number one pest in New Zealand.

Q: tree sap flow.

Q_c: tree sap flow per unit of projected crown area.

Reversion: spread of indigenous scrub across land after retirement of a land area by fencing and allowing natural succession to occur. Reversion also occurs when fertiliser and grazing management are insufficient.

Rust: poplar leaf diseases (*Melampsora spp.*).

RMA: Resource Management Act, enacted in 1991 in accordance to OECD countries and Uruguay Round agreements on the environment and development.

SAS: Statistical Analysis System.

Sandstone: a sedimentary rock composed of sand grains, compacted and weakly cemented by a small quantity of lime.

Sapwood: the outer and generally lighter coloured and less-durable wood which transports water and stores food (generally starch). It may represent 2-20 growth rings.

Sawlog: A log suitable in size and quality for the manufacture of sawn timber.

SEM: pooled standard error of the mean.

Shelterbelt: A long narrow strip of trees and/or shrubs intended to reduce wind flow, often for agricultural gain. Timber may be a by-product of shelterbelts.

Silviculture: the procedures used in growing trees, especially pruning and thinning.

Softwood: gymnosperms (conifers). The wood is structurally distinct from that of hardwoods (angiosperms) and may or may not be relatively soft physically.

Soil water balance: measurement of soil water content during a certain period while determining inputs and outputs.

SSS: soluble sugar and starch.

STGA: single tree gap area.

Stocking: the number of live trees per hectare, also denominated as "tree density".

SU: sheep unit.

T: tree transpiration.

Tephra: loose material, e.g., ash and pumice, deposited by volcanic eruptions; mantles extensive areas of the central North Island.

TCE: trichloroethylene.

TDM: total dry matter.

TDR: time domain reflectometry.

Tension wood: also denominated compression wood. Abnormal wood formed on the lower side of branches and leaning stems. Generally confers undesirable wood properties.

Th: Throughfall.

Thinning: the removal of trees within a stand at some time before clearfelling. If trees are left lying in the forest, it is "waste thinning" or "thinning to waste". If trees are extracted, it is "production thinning".

Topdress: aerial application seed or fertiliser to pasture or forestland. Land-base applications are generally termed as broadcast application.

TNC: total nonstructural carbohydrates.

TSP: triple super phosphahate.

UPA: understorey pasture acumulation.

Veneer: a thin sheet of wood produced by slicing or rotary peeling a log. Used for decoration on a cheaper substrate such as chipboard, or for making plywood.

v_c : sap flow velocity.

v_h : heat pulse velocity.

Widely space planting: low-density tree plantation looking after strategic planting of trees according to the eroded or erosion prone landscape.

α : statistical significance.

θ : soil water content.

ψ : hydraulic conductivity.

$\Delta\theta$: change in water stored within the soil stratum.

Ω : Omega factor, represents the dependence of transpiration on canopy conductance of climatic variables.

\emptyset : diameter.