New Zealand Land-use Hydrology:

An Annotated Bibliography

SMF2167: Report No 3

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Introduction

Project 2167: Land Cover Effects on Water Availability is funded by a grant from the Ministry for the Environment's Sustainable Management Fund. The purpose of the project is to provide information and tools that will assist water and land managers in making the best allocations of water resources for all end-users.

A series of bibliographies are planned as part of the project to provide information on hydrological data for *Pinus radiata (*radiata pine) plantations, Douglas fir (*Pseudotsuga menziesii)* forests and plantations, and New Zealand land-use studies.

This report contains information pertaining primarily to hydrological studies in New Zealand and is divided into five sections:

- Section 1 provides the background to the project.
- Section 2 (the coloured section) is designed to be a quick reference point to any topic. It lists keywords under three topic areas (hydrological topics, vegetation comparisons, land-use changes) and includes citations relevant to each keyword.
- Section 3 is the bibliography of relevant New Zealand scientific papers and reports. Each citation generally includes an abstract and further comment on the information presented. Citations are presented in alphabetical order of authors, and then by year of publication.
- Section 4 is a supplementary annotated listing of overseas scientific papers and reports on gorse, bracken and large catchments to supplement the limited New Zealand information. Each citation generally includes an abstract and further comment on the information presented. Citations are presented in order of topic, then by authors and, finally, in order of year of publication.
- Section 5 is a reference list of: (a) citations referred to in the document but not included in Sections 3 and 4; (b) unpublished contract reports; and (c) territorial authority reports. These references are not annotated but are included for completeness.

Section 1: Background

There are worldwide concerns that increased establishment of plantations of exotic forest species for wood fibre production, either as a result of conversion of native forests and scrublands or afforestation of pasture and native grasslands, may have a detrimental effect on the environment. New Zealand is no different to most other countries in this regard. Attention has focused on the following concerns:
- harvesting trees will cause accelerated erosion and sedimentation problems
- plantations are a monoculture, which decreases biodiversity
- acidification and compaction will degrade soil quality
- streams will dry up after planting forests, especially in the low-flow season.

However, there is evidence to show that for forest management in general:
- erosion and sedimentation issues are short term only, and when taken over the full rotation, plantation forests are often less damaging than other land uses (e.g., McLaren 1996, Phillips *et al.* 1990)
- plantations do sustain a wide-ranging biological diversity (e.g., Allen *et al.* 1995; Ledgard 1995)
- changes to soil quality may be positive (e.g., Davis & Lang 1991) and may often lead to improvements in hydrological properties (R.J. Jackson, unpublished data).

The main concern raised when proposals are made to establish plantation forests in the headwaters of catchments is that there could be diminished water yields. In water-short areas, conflicts can then arise between foresters who need to 'use' rain water to meet the biological needs of trees for growth, and downstream-users who require water for municipal, stock-water and irrigation supplies, or to sustain minimum levels in rivers for recreation, or to maintain in-stream habitats, especially at times of seasonally low flows. Water managers then have the unenviable task of allocating scarce resources to all users. Conflicts in the allocation process can lead to litigation in the Environmental Court.

The draft National Agenda for Sustainable Management Action Plan (MfE 1999) states 'There has been a substantial research effort in New Zealand and overseas on studying the impacts of changing land use on water yield, such as afforestation. This research is at a point where a guideline needs to be produced.' This document, and others in the series, while aimed at providing a foundation to reduce conflicts between land and water managers, could assist in the preparation of such a guideline.

SMF Project 2167: Land Cover Effects on Water Availability

Workshops in Nelson (March 1999 sponsored by Tasman District Council, Landcare Research, New Zealand Hydrological Society; Rowe 1999) and Rotorua (May 1999, New Zealand Forest Research Institute, Site Management for Sustainable Forestry) identified that water resource issues were still in the forefront of the list of concerns held by land managers (foresters, agriculturalists, etc.), water resource managers (regional and district councils) and other water users (recreationalists, environmentalists, etc.). Discussion with people outside these workshops indicated that these concerns were highly relevant. The principal questions confronting water resource managers were:
- What is the effect of a particular land use on useable water resources?
- How do I allocate scarce water resources when land-use change affects availability?
- What information, resources, and tools are available to help me with these questions?

In 1999, Tasman District Council and Landcare Research applied to the Ministry for the Environment's Sustainable Management Fund for funding to undertake a review of available literature, gather hydrological and land-use data from New Zealand catchments, and to develop a decision support resource to enable water and land managers to make more informed decisions on water resource allocations. The successful application resulted in this project, SMF2167: Land Cover Effects on Water Availability.

The New Zealand plantation forest estate

At 1 April 1999, the New Zealand exotic forest estate covered 1.73 m ha, 6% of New Zealand's land area. *Pinus radiata* D. Don is the number one plantation species grown comprising more than 1.56 m ha, over 90% of the total plantation area (NZFI undated). *Pinus radiata* is commercially grown mainly in rainfall regimes between 600 mm and 2500 mm/year, and below about 1000 m altitude. Douglas fir (*Pseudotsuga menziesii*) is the next most significant species planted, 86 000 ha, and is found mainly in the lower South Island or at higher altitudes, often above 1000 m. About 82 000 ha of other species are grown, including eucalypts (NZFI undated).

Between 1992 and 1999, new plantations were being established at over 60 000 ha per year, peaking in 1994 when about 96 000 ha were planted. Rates have dropped, however, and the provisional estimate for 1999 was about 25 000 ha (NZFI undated). Most of the new plantings are on pasture land both improved (about 45%) and unimproved (about 45%), with the balance in scrubland (12%) (MAF 2000).

Sources of hydrological data

Catchment studies at Glendhu (Otago), Maimai (West Coast), Donald Creek and Moutere (Nelson), Ashley (Canterbury) and Purukohukohu (Central North Island) provide the bulk of the information on the hydrology of New Zealand forests, and generally for *Pinus radiata* plantations or native forests. Apart from Moutere and Ashley, these are higher rainfall areas where concerns about water yields are not high. This is in contrast to, say, Nelson and the east coasts of both islands where water is often scarce in summer and the most relevant data comes from studies at Donald Creek, Moutere and Ashley. Hydrological studies at Makara (Wellington), Puketurua (Northland), Ashley, Moutere and Purukohukohu are the main sources of pasture catchment data while Glendhu provides information about native tussock grasslands. Reviews by Fahey & Rowe (1992), McLaren (1996) and Rowe *et al.* (1997) summarise some of these studies.

This bibliography

This bibliography focuses on New Zealand studies on the hydrology of land uses and is one of a series being prepared for the project. Further reports in this series pertain to specific land covers. Coverage of the world-wide literature pertaining to the hydrology of *radiata pine (Pinus radiata)* plantations can be found in Report No. 1 (Rowe *et al.* 2001b) while Report No. 2 (Rowe *et al.* 2001a) is a bibliography of the hydrology of Douglas fir (*Pseudotsuga menziesii*) forests and plantations. To be useful as a stand alone document, this bibliography contains New Zealand studies found in Reports 1 and 2.

Some studies report on the differences in water yield between catchments with different vegetation covers, e.g., indigenous forests, exotic plantations, grasslands, and pasture, while others focus on processes such as interception or transpiration. The bibliography's focus is hydrology, and water quality and other aspects are listed only when these accompany useful hydrological data.

New Zealand studies on gorse, bracken and large catchments are limited in number. To supplement these, the few studies from overseas that are relevant to the project have been included in Section 4. In the indexes these are identified by (S4) at the end of the author(s') name(s).

Reviews of catchment experiments from worldwide surveys have been presented by Hewlett & Hibbert (1967) and Bosch & Hewlett (1982). Stednick (1996) has done a similar study for the USA.

Section 2: Keyword Indices

Keywords have been used to provide a quick reference to relevant citations Their selection carries a degree of subjectivity, and they have been kept to a minimum to avoid a proliferation of terms.

Hydrological Topics:

Dew	
Evaporation	Total evaporation, i.e., evapotranspiration
Fog	
Interception	Rainfall and snowfall interception including all or some of throughfall, stemflow and interception loss = wet weather evaporation
Low flow	
Model	Used when the focus is on modelling
Nutrient cycling	Mainly canopy interactions but includes some soil-related work
Review	Used when the focus of a report is a review of many studies
Soil water	
Stemflow	
Storm flow	Includes peak flow and quickflow
Throughfall	
Transpiration	Dry canopy evaporation
Tree growth	
Water balance	Studies where the water balance is determined
Water quality	Used when this is a major focus of the paper
Water yield	Total streamflow for a given period

Vegetation Class:

Conifers	Does not include pine species/Douglas fir
Douglas fir	
Mixed	Usually forest and grassland/pasture
Native evergreen forest	
Native grassland	
Pasture	
Pinus radiata	
Pine species	
Scrubland (Bracken)	
Scrubland (Gorse)	
Scrubland (Manuka)	
Scrubland (Other)	

Land-use Changes:

Afforestation (includes from scrubland)	
Conversion from one forest to another	
Drainage	
Forest management	
Harvesting	Of *P. radiata* or Douglas fir stands otherwise in Conversion
Irrigation	
Pasture management	
Scrub to pasture conversion	

Hydrological Topics Index

Waugh, J.R. 1970a
Waugh, J.R. 1970b

Model
McMurtrie, R.E. et al. 1990
Miller, B.J. 2000
Whitehead, D. 1987
Whitehead, D.; Kelliher, F.M. 1991a
Whitehead, D.; Kelliher, F.M. 1991b
Whitehead, D. et al. 1989

Nutrient cycling
Baker, T.G.; Hodgkiss, P.D.; Oliver, G.R. 1985
Baker, T.G.; Oliver, G.R.; Hodgkiss, P.D. 1986
Levett, M.P. 1978
Miller, R.B. 1963
Will, G.M. 1959a

Review
Fahey, B. 1994
Fahey, B.D.; Rowe, L.K. 1992
Jackson, R.J. 1992
Rowe, L. et al. 1997
Waugh, J.R. 1980

Soil water
Duncan, M.J. 1993
Hayman, J.M.; Stocker, R.V. 1982
Jackson, D.S. et al. 1983
Jackson, R.J. 1985a
Jackson, R.J.; Marden, M.; Payne, J. 1987
Jackson, R.J.; Rowe, L.K. 1997a
Kelliher, F.M. et al. 1992
Knight, P.J.; Will, G.M. 1977
Martin, R.J. 1990
McAneney, K.J.; Judd, M.J. 1983
McMurtrie, R.E. et al. 1990
Parfitt, R.L. et al. 1985
Scotter, D.R. Clothier, B.E.; Turner, M.A. 1979

Stemflow
Aldridge, R.; Jackson, R.J. 1968
Aldridge, R.; Jackson, R.J. 1968
Blake, G.J. 1965
Blake, G.J. 1972
Blake, G.J. 1975
Duncan, M.J. 1980
Duncan, M.J. 1995a
Fahey, B.D. 1999
Fahey, B.; Watson, A.; Payne, J. 2001
Kelliher, F.M. et al. 1992
McGregor, K.R. 1983
Rowe, L.K. 1975
Rowe, L.K. 1979
Rowe, L.K. 1983
Rowe, L.K.; Marden, M,; Rowan, D. 1999

Storm flow
Dell, P.M. 1982
Dons, A. 1981
Dons, A. 1987
Duncan, M.J. 1980
Duncan, M.J. 1983
Duncan, M.J. 1995a
Duncan, S.H. 1986 (S4)
Fahey, B.D. 1990
Fahey, B. 1994
Fahey, B.D.; Jackson, R.J. 1995
Fahey, B.D.; Jackson, R.J. 1997a
Fahey, B.D.; Rowe, L.K. 1992
Fahey, B.D.; Watson, A.J. 1991
Hicks, D.M. 1988
Jackson, R.J. 1973
Jackson, R.J. 1984
Jackson, R.J. 1985b
Jackson, R.J. 1987
Jackson, R.J.; Fahey, B.D. 1993
Jackson, R.J.; Rowe, L.K. 1996
O'Loughlin, C.L. et al. 1978.
Pearce, A.J. 1980
Pearce, A.J.; McKerchar, A.I. 1979
Pearce, A.J. et al. 1976
Rowe, L. et al. 1997
Scarf, F. 1970
Smith, P.J.T. 1987
Williams, P.W. 1976

Throughfall
Aldridge, R. 1968

Aldridge, R.; Jackson, R.J. 1968
Aldridge, R.; Jackson, R.J. 1968
Baker, T.G.; Hodgkiss, P.D.; Oliver, G.R. 1985
Baker, T.G.; Oliver, G.R.; Hodgkiss, P.D. 1986
Blake, G.J. 1965
Blake, G.J. 1972
Blake, G.J. 1975
Calvo de Anta, R. et al. 1979 (S4)
Duncan, M.J. 1980
Duncan, M.J. 1995a
Egunjobi, J.K. 1971
Fahey, B.D. 1964
Fahey, B.D. 1999
Fahey, B.; Watson, A.; Payne, J. 2001
Hogg,S.E.; Murray, D.L.; Manly, B.J.F. 1978
Jackson, R.J. 1985b
Kelliher, F.M. et al. 1992
Levett, M.P. 1978
McGregor, K.R. 1983
Miller, R.B. 1963
Rowe, L.K. 1975
Rowe, L.K. 1979
Rowe, L.K. 1983
Rowe, L.K.; Marden, M,; Rowan, D. 1999
Soto, B.; Diaz-Fierros, F. 1997 (S4)
Will, G.M. 1955
Will, G.M. 1959a
Will, G.M. 1959b
Will, G.M. 1962

Transpiration
Arneth, A. et al. 1998
Benecke, U.; Evans, G. 1987
Campbell, D.I. 1989
Campbell, D.I.; Murray, D.L. 1990
Fahey, B.; Watson, A.; Payne, J. 2001
Kelliher, F.M. et al. 1990
Lockwood, et al. 1986 (S4)
Miller, B.J. et al. 1998
Murray, D.L. et al. 1991
Pearce, A.J. et al. 1987
Pitman, J.I.; Pitman, R.M. 1986 (S4)
Roberts, J. 1986 (S4)
Roberts, J. et al. 1980 (S4)
Swanson, R.H. 1981
Whitehead, D.; Kelliher, F.M. 1991b
Whitehead, D. et al. 1989
Whitehead, D. et al. 1994

Tree growth
Brownlie, R.K.; Kelliher, F.M. 1989

Water balance
Blake, G.J.; Carlile, H.A. 1972
Dons, A. 1987
Fahey, B.D.; Rowe, L.K. 1992
Fahey, B.D.; Watson, A.J. 1991
Fahey, B.; Watson, A.; Payne, J. 2001
Jackson, R.J. 1972
Murray, D.L. et al. 1991
Pearce, A.J. et al. 1980
Pearce, A.J. et al. 1982
Pearce, A.J. et al. 1984
Pearce, A.J.; Rowe, L.K.; Stewart, J.B. 1980
Whitehead, D.; Kelliher, F.M. 1991a
Whitehead, D.; Kelliher, F.M. 1991b
Whitehead, D. et al. 1989

Water quality
Bargh, B.J. 1977
Bargh, B.J. 1978
Claridge, G.G.C. 1970
Cooper, A.B.; Thomsen, C.E. 1988
Fahey, B.D.; Jackson, R.J. 1997b
Graynoth, E. 1979
Graynoth, E. 1992
Hicks, D.M. 1988
Holdsworth, D.K.; Mark, A.F. 1990
McColl, R.H.S.; White, E.; Gibson, A.R. 1977
O'Loughlin, C.L. et al. 1978.
Pearce, A.J. et al. 1976
Rowe, L.K.; Fahey, B.D. 1988
Rowe, L.K.; Fahey, B.D. 1991
Smith, C.M. 1992

Water yield
Bargh, B.J. 1977
Bargh, B.J. 1978
Barton, I.L. 1972
Barton, I.L; Card, J.H. 1979
Calder, I.R. 1996

Cameron, C.S. et al. 1997
Campbell, D.I.; Murray, D.L. 1990
Cameron, C.S. et al. 1997
Claridge, G.G.C. 1970
Cooper, A.B.; Thomsen, C.E. 1988
Dell, P.M. 1982
Dons, A. 1980
Dons, A. 1981
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Duncan, M.J. 1980
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Fahey, B.D.; Jackson, R.J. 1997b
Fahey, B.; Jackson, R.; Rowe, L.K. 1998a
Fahey, B.; Jackson, R.; Rowe, L.K. 1998b
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Fahey, B.D.; Watson, A.J. 1991
Graynoth, E. 1979
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Hewitt, A.M.; Robinson, A. 1983a
Hewitt, A.M.; Robinson, A. 1983b
Holdsworth, D.K.; Mark, A.F. 1990
Jackson, R.J. 1972
Jackson, R.J. 1973
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Jackson, R.J. 1987
Jackson, R.J. 1992
Jackson, R.J.; Payne, J. 1995
Jackson, R.J.; Rowe, L.K. 1997b
Mark, A.F.; Rowley, J. 1976
McColl, R.H.S.; White, E.; Gibson, A.R. 1977
McKerchar, A.I. 1980
McKerchar, A.I.; Waugh, J.R. 1976
Patric J.H.; Gould, E.M. 1976 (S4)
Pearce, A.J. 1980
Pearce, A.J. et al. 1987
Pearce, A.J.; O'Loughlin, C.L. et al. 1976
Pearce, A.J.; Rowe, L.K. 1979a
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Pearce, A.J.; Rowe, L.K.; Stewart, J.B. 1980
Pitman, W.V. 1978 (S4)
Riddell, J.M; Martin, G.N. 1982
Rowe, L.K. 1998
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Scarf, F. 1970
Schouten, C.J.J.H. 1976
Smith, C.M. 1992
Smith, J.L.H. 1946
Smith, P.J.T. 1987
Toebes, C.; Scarf, F.; Yates, M.E. 1968
Trimble, S.W.; Weirich, F.H. 1987 (S4)
Trimble, S.W. et al. 1987 (S4)
Waugh, J.R. 1980
Whitehead, D.; Kelliher, F.M. 1991a
Wilkie, D.R.; Dixie, R.C.; Yates, M.E. 1965
Yates, M.E. 1964
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Vegetation Class Index

Campbell, D.I. 1989
Campbell, D.I.; Murray, D.L. 1990
Fahey, B.D. 1990
Fahey, B. 1994
Fahey, B.D.; Jackson, R.J. 1995
Fahey, B.D.; Jackson, R.J. 1997a
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Fahey, B.; Jackson, R.; Sutcliffe, C. 1991
Fahey, B.D.; Rowe, L.K. 1992
Fahey, B.D.; Watson, A.J. 1991
Holdsworth, D.K.; Mark, A.F. 1990
Mark, A.F.; Rowley, J. 1976
Murray, D.L. et al. 1991
Pearce, A.J. et al. 1984
Rowe, L. et al. 1997

Pasture

Bargh, B.J. 1978
Beets, P.N.; Brownlie, R.K. 1987
Brownlie, R.K.; Kelliher, F.M. 1989
Cooper, A.B.; Thomsen, C.E. 1988
Dell, P.M. 1982
Dons, A. 1981
Dons, A. 1987
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Duncan, M.J. 1983
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Hayman, J.M.; Stocker, R.V. 1982
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Toebes, C.; Scarf, F. Yates, M.E. 1968
Waugh, J.R. 1980
Wilkie, D.R.; Dixie, R.C.; Yates, M.E. 1965
Williams, P.W. 1976
Yates, M.E. 1964
Yates, M.E. 1971

Pinus radiata

Arneth, A. et al. 1995
Arneth, A. et al. 1998
Baker, T.G.; Hodgkiss, P.D.; Oliver, G.R. 1985
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Black, R.D. 1990
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Brownlie, R.K.; Kelliher, F.M. 1989
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Dons, A. 1980
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Duncan, M.J. 1980
Duncan, M.J. 1983
Duncan, M.J. 1993
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Duncan, M.J. 1995b
Fahey, B.D. 1964
Fahey, B.D. 1990
Fahey, B.D. 1994
Fahey, B.D. 1999
Fahey, B.D. 2000
Fahey, B.; Jackson, R. 1995
Fahey, B.; Jackson, R. 1997a
Fahey, B.; Jackson, R. 1997b
Fahey, B.; Jackson, R.; Rowe, L.K. 1998a
Fahey, B.; Jackson, R.; Rowe, L.K. 1998b
Fahey, B.D.; Rowe, L.K. 1992
Fahey, B.; Watson, A. 1991
Fahey, B.; Watson, A.; Payne, J. 2001
Graynoth, E. 1979
Graynoth, E. 1992
Herald, J. 1978
Herald, J. 1979
Hewitt, A.M.; Robinson, A. 1983a
Hewitt, A.M.; Robinson, A. 1983b
Hicks, D.M. 1988
Jackson, D.S. et al. 1983
Jackson, R.J. 1983
Jackson, R.J. 1985a
Jackson, R.J. 1985b
Jackson, R.J. 1992
Jackson, R.J.; Fahey, B.D. 1993
Jackson, R.J.; Marden, M.; Payne, J. 1987
Jackson, R.J. Payne, J. 1995
Jackson, R.J.; Rowe, L.K. 1996
Jackson, R.J.; Rowe, L.K. 1997a
Jackson, R.J.; Rowe, L.K. 1997b
Kelliher, F.M. et al. 1990
Kelliher, F.M. et al. 1992
Knight, P.J.; Will, G.M. 1977
Levett, M.P. 1978
McGregor, K.R. 1983
McKerchar, A.I. 1980
McMurtrie, R.E. et al. 1990
Miller, B.J. 2000
Miller, B.J. et al. 1998
Pearce, A.J. et al. 1987
Riddell, J.M.; Martin, G.N. 1982
Rowe, L.K. 1998
Rowe, L.K.; Fahey, B.D. 1988
Rowe, L.K.; Fahey, B.D. 1991
Rowe, L.K. et al. 1997
Rowe, L.K.; Pearce, A.J. 1994
Rowe, L.K. et al. 1994
Smith, J.L.H. 1946
Smith, P.J.T. 1987
Waugh, J.R. 1980
Wells, L.P.; Blake, G.J. 1972
Whitehead, D. 1987
Whitehead, D.; Kelliher, F.M. 1991a
Whitehead, D.; Kelliher, F.M. 1991b
Whitehead, D. et al. 1989
Whitehead, D. et al. 1994
Will, G.M. 1955
Will, G.M. 1959a
Will, G.M. 1959b
Will, G.M. 1962
Yunusa, I.A.M. et al. 1995

Pine species

Graynoth, E. 1979
Graynoth, E. 1992
McKerchar, A.I. 1980
Swanson, R.H. 1981
Will, G.M. 1959a

Scrubland (Bracken)

Lockwood, J.G. et al. 1986 (S4)
Pitman, J.I. 1989 (S4)
Pitman, J.I.;Pitman, R.M. 1986 (S4)
Pitman, J.I.;Pitman, R.M. 1990 (S4)
Roberts, J. 1986 (S4)
Roberts, J. et al. 1980 (S4)
Smith, R.T.; Lockwood, J.G. 1990 (S4)
Williams, A.G. et al. 1987 (S4)

Scrubland (Gorse)

Aldridge 1968
Blake, G.J. 1972
Blake, G.J. 1975
Calvo, R.N. et al. 1979 (S4)
Duncan, M.J. 1980
Duncan, M.J. 1983
Duncan, M.J. 1993
Duncan, M.J. 1995a
Egunjobi, J.K. 1971
Jackson, R.J. 1992
Scarf, F. 1970

Soto, B.; Diaz-Fierros, F. 1997 (S4)

Scrubland (Manuka)

Aldridge, R.; Jackson. R.J. 1968
Blake, G.J. 1965
Blake, G.J. 1972
Blake, G.J. 1975
Jackson, R.J. 1987
McColl. R.H.S.; White, E.; Gibson, A.R. 1977
Rowe, L.K.; Marden, M.; Rowan, D. 1999
Schouten, C.J.J.H. 1976

Scrubland (Other)

Barton, I.L 1972
Barton, I.L; Card, J.H. 1979
Fahey, B. 1994
Fahey, B.D.; Rowe, L.K. 1992
Herald, J. 1978
Herald, J. 1979
McKerchar, A.I. 1980
Pearce, A.J. 1980
Pearce, A.J.; McKerchar, A.I. 1979
Pearce, A.J.; Rowe, L.K. 1979a
Rowe, L. et al. 1997
Wells, L.P.; Blake, G.J. 1972

Land-use Change Index

Scarf, F. 1970
Schouten, C.J.J.H. 1976

Urbanization
Williams, P.W. 1976

Section 3: New Zealand Bibliography

Citations are listed in alphabetical order of author(s), then by date. If a citation has no annotations, the paper may or may not have been scanned but is still listed as being of possible relevance to the subject.

Many of the abstracts included here come directly from literature searches, but they can be different from the abstracts in the papers. Where known, CAB Abstracts Accession (AN) numbers are given. Other annotations extracted from the papers, indicated by '*Comment*', are considered by the authors of this report to be important relevant information. Abstracts may have been shortened to only include information of relevance to this study.

Where a physical copy of a paper has been obtained, a location reference such as R1234 or LKR indicates the reference number in the collection of Lindsay Rowe. 'Not sighted' means the report was not found in the New Zealand library system.

Tables in this report are LKR's version of data extracted from the papers listed and may not be the same as those found in the original papers. In the absence of tables, data have sometimes been extracted from figures and, therefore, may not be entirely accurate. While care has been taken to ensure the information presented here is accurate, it is the responsibility of the user to ensure that the transcriptions and interpretations made are correct, and relevant to a particular situation. Only publications in English or English annotations, abstracts and captions have been scrutinised fully.

A summary table modified from that below has been used with many citations to provide a quick reference to the thrust of the report, and a guide to the plantation parameters. A negative age implies pre-planting or calibration data are available.

Country:	Duration:	Report Location:
Vegetation:		
Land-Use Change:		
Stand Type: Plantation	Stand Density:	Basal Area:
Height:	Diameter:	Rainfall:
Keywords:		

Where necessary, imperial units have been converted to metric equivalents.

Abbreviations

Abbreviations used by LKR in the tables and *Comments* (may be in lowercase or uppercase)

BA	Basal area	RO	Runoff (= streamflow = water yield)
DBH	Diameter at breast height	SF	Stemflow
E	Evaporation	SM	Soil moisture
ET	Evapotranspiration	SPH	Number of stems per hectare
IL	Interception loss	SWD	Soil water deficit
LAI	Leaf area index	TRANS	Transpiration
MAP	Mean annual precipitation	TF	Throughfall
PTTN	Precipitation	Yr	Year(s)

Aldridge, R. 1968: Throughfall under gorse (*Ulex europaeus*) at Taita, New Zealand. New Zealand Journal of Science 11: 447–451.

Country: New Zealand	Duration: Mar–Dec 1966	Report Location: R222
Vegetation: Scrubland (Gorse)		
Stand type: Natural regeneration, 7 y	Stand Density: 478000 sph	
Height: 0.9–1.2 m	Diameter: < 25 mm	
Keywords: Throughfall		

Comment
Plot within the Taita Exotic Forest Catchment—autumn through early summer

Throughfall % increased as storm size increased and averaged 24% for storms over 2.4 mm precipitation.
On a storm basis:

Throughfall = 0.23 × Precipitation − 0.05 r = 0.97
Precipitation = 625 mm; Throughfall = 144 mm = 23% of precipitation.

Aldridge, R.; Jackson, R. J. 1968: Interception of rainfall by manuka (*Leptospermum scoparium*) at Taita, New Zealand. New Zealand Journal of Science 11: 301–317.

Country: New Zealand	Duration: Apr–Dec 1966	Report Location: R223
Vegetation: Scrubland (Manuka)		
Stand type: Natural regeneration, 58 y	Stand Density: ~ 40000 sph	
Height: 5 m	Diameter: 25–60 mm	
Keywords: Interception; Stemflow; Throughfall		

Comment
Plot within the Taita Native Catchment—autumn through early summer

Throughfall % increased as storm size increased.
On a storm basis:

Throughfall = 0.454 × Precipitation − 0.025 r = 0.988
Stemflow = 0.23 × Precipitation − 0.05 r = 0.97
Net rainfall = 0.742 × Precipitation − 0.15 r = 0.982

For the period of good data (52 of the 62 storms) throughfall = 38.5% of precipitation, stemflow = 22.7%, net rainfall = 61.3% and interception loss = 38.7%
For MAP = 1370 mm, IL is estimated to be 530 mm.

Aldridge, R.; Jackson, R. J. 1973: Interception of rainfall by hard beech (*Nothofagus truncata*) at

Taita, New Zealand. New Zealand Journal of Science 16: 185–198.

Country: New Zealand	Duration: 1 year	Report Location: R221
Vegetation: Native evergreen forest		
Stand type: Natural regeneration, 100–120 y	Stand Density: ~ 200 sph	
Height: 10–15 m	Diameter: 20–60 cm	
Keywords: Interception; Stemflow; Throughfall		

Comment
Plot within the Taita Native Catchment.

Throughfall % increased as storm size increased.
On a storm basis:

Throughfall = 0.526 × Precipitation − 0.71 r = 0.985
Stemflow = 0.184 × Precipitation − 0.33 r = 0.947
Net rainfall = 0.708 × Precipitation − 1.04 r = 0.981

For 12 months with 1530 mm precipitation, estimated throughfall = 48.5% (740 mm) and stemflow = 17.8% (270 mm).

Arneth, A.; Kelliher, F.M.; McSeveny, T.M.; Byers, J.N. 1995: Water use efficiency of a dryland *Pinus radiata* plantation. New Zealand Meteorological and Hydrological Symposium, Christchurch 1995. (Unpublished)

Country: New Zealand	Duration: 18 days in 1 yr	Report Location: LKR
Vegetation: *P. radiata*		
Stand Type: Plantation 8 yr	Stand Density: 1250 SPH	
Height: 9 m		Rainfall: 665 mm
Keywords: Evaporation		

Comment
During the course of the study, the forest evaporation rate declined from 3.7 mm/day (17–26 November) to 2.9 mm/day (12–13 January) to 2.2 mm/day (18–27 March) to 1.0 mm/day (14–20 July). Ground evaporation was 20–25% of the total except when the ground was frozen in winter.

Arneth, A.; Kelliher, F.M.; McSeveny, T.M.; Byers, J.N. 1998: Fluxes of carbon and water in a *Pinus radiata* forest subject to soil water deficit. Australian Journal of Plant Physiology 25: 557–570.

Country: New Zealand	Duration: 6–9 d, 7 times over 18 months	Report Location: R1346
Vegetation: *P. radiata*		
Stand Type: Plantation 8+ yr	Stand Density: 1220 SPH thinned to 860 SPH	
Height: 8.5 m		Rainfall: 658 mm/yr
Keywords: Evaporation; Transpiration		

CAB Abstracts AN 980612668

Seasonal CO2 (FCO2) and water (E) fluxes were measured by eddy covariance, in an 8-yr-old *P. radiata* plantation in New Zealand subject to growing season soil water deficit. Average rates of FCO2 and E were highest in spring (324 mmol/m^2/d and 207 mol/m^2/d, respectively) when the abiotic environment was most favourable for surface conductance and photosynthesis. During summer, fluxes were impeded by soil water (theta) deficit and were equal to or smaller than during winter (FCO_2 = 46 mmol/m^2/d in summer and 115 mmol/m^2/d in winter; E = 57 and 47 mol/m^2/d, respectively). On particularly hot and dry days, respiration exceeded photosynthetic uptake and the ecosystem was a net carbon source. Portraying the underlying biochemistry of photosynthesis, daytime half-hourly FCO_2 increased with quantum irradiance absorbed by the canopy (Qabs) following a non-saturating, rectangular hyperbola. Except for winter, this relation was variable, including hysteresis attributable to diurnal variation in air saturation deficit (D). Daily ecosystem , FCO_2 /Qabs and/E were inversely proportional to maximum daily D, but in the cases of FCO_2 and FCO_2/Qabs only after soil moisture deficit became established. Consequently, as the tree growing season progressed, ecosystem carbon sequestration was strongly limited by the co-occurrence of high D at low theta.

Comment

Balmoral Forest, North Canterbury. Start: 8-yr-old, HT 8.5 m, 1200 SPH, LAI 6.5. Finish: 10-yr-old, 860 SPH, LAI 5.6. Closed canopy throughout. Very stony sandy loam soils. MAP 658 mm; Dec.–Mar. 203 mm.

For well-watered soils, the total forest evaporation rate was 0.8 mm/d in winter; 3.7 mm/d in summer; range 0.4 to 4.8 mm/d. As the soil dried out and atmospheric demand increased, E declined to 1 mm/d.

There was considerable evaporation from the ground. Of total E, it was 24% in late spring, 42% in dry summer; 12% in winter; and 15% in early spring.

Baker, T.G.; Hodgkiss, P.D.; Oliver, G.R. 1985: Accession and cycling of elements in a coastal stand of *Pinus radiata* D.Don in New Zealand. Plant and Soil 86: 303–307.

Country: New Zealand	Duration: 1 yr	Report Location: R12
Vegetation: *P. radiata*		
Stand Type: Plantation 14 yr	Stand Density: 2100 SPH	Basal Area: 42 m^2/ha
Height: 19 m		Rainfall: MAP 1000 mm
Keywords: Nutrient cycling; Throughfall		

CAB Abstracts AN S083515/Authors' abstract

The accession and cycling of elements in a 14-year-old coastal stand of *P. radiata* was measured for 1 yr. The element contents (mg/m^{2}/yr) of bulk precipitation and throughfall respectively were: NO_3-N 41, 12; NH_4-N 133, 154; organic-N 157, 396; Na 4420, 9700; K 387, 2900; Ca 351, 701; Mg 486, 1320. Of the increase in elemental content of rainwater beneath the forest canopy 20% (NH_4-N), 70% (organic-N), 3% (Na), 90% (K), 20% (Ca) and 30% (Mg) was attributed to leaching; the remainder to washing of aerosols filtered from the atmosphere by the vegetation. The canopy absorbed approximately 40 mg/m^{2}/yr of NO_3-N. Litterfall was the major pathway for the above-ground biogeochemical cycle of N (93%), Ca (96%) and Mg (74%), and leaching was the major (73%) pathway for K.

Comment

Woodhill Forest, Auckland. Monthly samples, throughfall gauges moved each month. One year of data.

PTTN = 895 mm, TF = 512 ± 10 mm (57% of P).
Stemflow was not measured.

Baker, T.G.; Oliver, G.R.; Hodgkiss, P.D. 1986: Distribution and cycling of nutrients in *Pinus radiata* as affected by past lupin growth and fertilizer. Forest Ecology and Management 17: 169–187.

Country: New Zealand	Duration: 1 yr	Report Location: R1579
Vegetation: *P. radiata*		
Stand Type: Plantation 14 yr	Stand Density: 2000 SPH	Basal Area: See below
Height: See below		Rainfall: 822 mm/yr
Keywords: Nutrient cycling; Throughfall		

Comment

Woodhill Forest, Auckland. 14-yr-old, 2000 SPH; stabilised sand dune. Study period 12 months.

Stand characteristics

	Control plot	Lupin	Fertiliser	Lupin+fertiliser
Ht (m)	16.4	18.2	19.8	20.0
BA m^2/ha	29.9	36.1	38.9	47.5

PTTN = 822 mm
Throughfall:
Control 551 mm (67%)
Lupin 484 mm (59%)
Fertiliser 484 mm (59%)
Lupin+fertiliser 459 mm (56%) This plot had greater needle mass

Bargh, B.J. 1977: Output of water, suspended sediment and phosphorus and nitrogen forms from a small forested catchment. New Zealand Journal of Forestry Science 7: 162–171.

Country: New Zealand	Duration: 1 year	Report Location: LKR
Vegetation: Native evergreen forest		
Stand type: Natural forest		
Keywords: Interception ; Water quality; Water yield		

Comment
Ballance Catchment, northern Tararua Ranges. MAP = 1200 mm. Area not stated. Same data period as Bargh (1978).

The stream ceased flowing for 18 days in January through April.
Precipitation 1202 mm; streamflow 158 mm (14% of precipitation).
Forest interception loss ~ 30%.

Bargh, B.J. 1978: Output of water, suspended sediment and phosphorus and nitrogen forms from a small agricultural catchment. New Zealand Journal of Agricultural Research 21: 29–38.

Country: New Zealand	Duration: 1 year	Report Location: LKR
Vegetation: Pasture		
Keywords: Water quality; Water yield		

Comment
Tuapaka Catchment, northern Tararua Ranges. Average precipitation (5 years) 1050 mm. Area 180 ha. Same data period as Bargh (1977).

Precipitation 1048 mm; streamflow 273 mm (26% of precipitation).

Barton, I.L 1972: The practice of forestry within Auckland's operating water catchments

Proceedings, New Zealand Ecological Society 19: 46–56.

Country: New Zealand	Duration: 3 years	Report Location: R239
Vegetation: Scrubland		
Land-Use Change: Afforestation (scrub to plantation)		
Stand type: Plantation -1 to +1 y		
Keywords: Water yield		

Comment
Introduces an experimental programme established in the Hunua Ranges near Auckland in 1969 when monitoring began on three catchments in native scrub. In 1970, two were cleared and burned and then planted in *C. japonica* or *P. radiata*. There are small wetlands in the lower part of the catchment which were not planted. See Barton and Card (1979) for details.

Comparing flows between the control catchment and the burned catchments for the 9 months before and the 9 months after the burn indicated an annual water yield increase of between 200 and 220 mm.

Barton, I.L; Card, J.H. 1979: A comparison of vegetation mass, species and runoff on three experimental catchments in the Hunua Ranges Auckland Regional Authority Forestry Section Water Department Technical Report No G/3, (unpublished).

Country: New Zealand	Duration: 10 yr	Report Location: R1481
Vegetation: Conifer; *P. radiata*; Scrubland		
Land-Use Change: Afforestation (scrub to plantation)		
Stand Type: Plantation −1 to +8 yr		
Keywords: Water yield		

Comment
An experimental programme was established in the Hunua Ranges near Auckland in 1969 when monitoring began on three catchments in native scrub. In 1970, two were cleared and burned and then planted in *Cupressus japonica* or *P. radiata*. There are small wetlands in the lower part of the catchment, which were not planted.

Catchment parameters

Catchment	Vegetation	Area (ha)	Wetland (ha)
North	Control scrub	8.84	0.17
Central	*C. japonica*	11.42	0.40
South	*P. radiata*	14.98	0.81

The following table does not take into account the unplanted area and assumes the wetland performs the same before and after planting (flow calculated from total volumes by LKR).

Water yield at Hunua

	Control		*P radiata*		*C japonica*	
	Precipitation (mm)	Streamflow (mm)	Precipitation (mm)	Streamflow (mm)	Precipitation (mm)	Streamflow (mm)
1969	1580	756	1515	646	1536	660
1970	1786	989	1712	978	1736	1028
1971	2046	1154	1961	1048	1989	1102
1972	1698	829	1627	743	1650	800
1973	1382	500	1325	386	1344	446
1974	1563	600	1498	414	1519	596
1975	1922	907	1842	614	1868	836
1976	2014	919	1930	591	1958	830
1977	1794	868	1720	458	1744	765
1978	1661	766	1592	357	1615	611

Beets, P.N.; Brownlie, R.K. 1987: Puruki experimental catchment: site, climate, forest management, and research. New Zealand Journal of Forestry Science 17: 137–160.

Country: New Zealand	Duration: 15 yr	Report Location: R102
Vegetation: Native evergreen forest; Pasture		
Land-Use Change: Afforestation		

CAB Abstracts AN900646467

Multidisciplinary research has been undertaken at the Purukohukohu experimental basin, particularly in the Puruki catchment over the past 15 yr. This period covers the conversion of Puruki from pasture to *P. radiata*, the development of the trees to canopy closure, and the effects of differential intensities of thinning on growth to the middle of the rotation. Puruki is a 35-ha catchment located at the southern end of the Paeroa Range in the central North Island of New Zealand, at 600 m altitude. The rhyolitic pumice soil, previously under rye grass/clover pasture and regularly treated with fertiliser, provides ample moisture and nutrients for *P. radiata* growth under the climatic conditions: 1500 mm of evenly distributed rainfall annually, 5 GJ/m^2 of solar irradiance annually, and average monthly temperatures of between 5° and 15°C. Puruki was uniformly planted with *P. radiata* at 2200 stems/ha in 1973, and trees in the individual subcatchments (Tahi, Rua and Toru) were progressively pruned to 2.2 m height and thinned to 160, 550 and 290 stems/ha respectively by 1985, with further thinning intended. A part of Rua was left unthinned as a control. In closed canopy stands periodic volume increment attains 52 m^3/ha p.a. The removal of between half and three-quarters of the tree basal area every 3 to 4 yr reduced volume increment to between 25 and 30 m^3/ha p.a., but this is likely to increase when management thinning is completed and the stand leaf area can increase uninterrupted to unthinned levels.

Comment
Provides forest stand and climate information relevant to the hydrological studies made by others.

Benecke, U.; Evans, G. 1987: Growth and water use in *Nothofagus truncata* (hard beech) in temperate hill country, Nelson, New Zealand. *In*: Yang Hanxi; Wang Zhan; Jeffers, J.R.N.; Ward, P.A. (Eds). The temperate forest ecosystem. Institute of Terrestrial Ecology, Grange-over-Sands. United Kingdom. P131–140.

Country: New Zealand	Duration: 1 yr	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Transpiration		

Comment
A stand at Donald Creek, Nelson.
Annual transpiration loss = 423 mm/year = 28% or precipitation.
Mean monthly values ranged between 0.3 mm/day in June and 2.7 mm/day in February for rainfree days (defined as having <0.1 mm precipitation).

Black, R.D. 1990: Esk catchment. Forest development and its effect on the water resource. New Zealand Hydrological Society Symposium, Taupo 1990. (Unpublished)

Country: New Zealand	Report Location: LKR
Vegetation: *P. radiata*	
Land-Use Change: Afforestation (reverting pasture)	
Keywords: Low flow	

Comment
Complements Black (1992) in that there is a diagram of annual plantings in the Esk catchment. Hydrological data limited to monthly discharge/rainfall (in L/s/mm) ratio for Dec.–Jan. each year.

Black, R. 1992: Esk River catchment—the influence of lithology and land use on water yield. In: Henriques, P. (Ed.) Sustainable Land Management. The Proceedings of the International Conference on Sustainable Land Management, Napier, November 1991. p259–267.

Country: New Zealand	Report Location: R1573
Vegetation: *P. radiata*	
Land-Use Change: Afforestation (reverting pasture)	
Keywords: Low flow	

Comment
Shows geology has a significant effect on catchment low flow.
States that vegetation (afforestation, 21% of the catchment) has no effect on baseflow. Does not provide the time frame and extent of afforestation given and how it changes and overlaps with the hydrological data to back up that statement. Plantations had been established by 1943 but the flow data are from 1967. Tabulates minimum summer month flows but presents no trend analyses.
See Black (1990) for some forest planting data.

Blake, G.J. 1965: Measurement of interception loss in teatree. Journal of Hydrology (New Zealand) 4:87.

Country: New Zealand	Duration: 5 months	Report Location: R858
Vegetation: Shrubland (teatree = manuka)		
Height: 3.6 m	Diameter: 1.2–4.3 cm	
Keywords: Interception; Stemflow; Throughfall		

Comment
Puketurua Basin, Northland.

Teatree interception, Puketurua

	Amount (mm)	Amount (%)
Precipitation	630	100
Throughfall	235	37.6
Stemflow	200	31.2
Interception loss	195	31.2

Blake, G.J. 1972: Interception and phytomorphology. New Zealand Ministry of Works, Water and Soil Conservation Hydrological Research Progress Report No.9. 27p. (Unpublished)

Country: New Zealand	Duration: 1 yr	Report Location: R1322
Vegetation: Native evergreen forest; *P. radiata*; Scrubland (gorse, manuka)		
Keywords: Interception; Stemflow; Throughfall		

Comment
Gives data as storm-based regression relationships for a number of New Zealand sites.

Whakarewarewa, Rotorua—*P. radiata*
interception loss = 0.274 × precipitation + 1.454 r = 0.801

Puketurua Basin, Northland—Manuka—storms > 4 mm.

throughfall	= −0.441 × precipitation + 0.037	r = 0.981
stemflow	= 0.425 × precipitation − 0.050	r = 0.967
net precipitation	= 0.847 × precipitation − 0.073	r = 0.964
interception loss	= 0.155 × precipitation + 0.072	r = 0.548

Otutira, Taupo—regenerating native forest
interception loss = 0.060 × precipitation + 1.568 r = 0.513

Moutere, Nelson—gorse
interception loss = 0.454 × precipitation + 1.520 'Fitted by eye'

Blake, G.J. 1975: The interception process. In: Chapman, T.G. (Ed). Prediction in catchment hydrology. Australian Academy of Sciences. Pp. 59–81.

Country: New Zealand	Report Location: R1509
Vegetation: Native evergreen forest; *P. radiata*; Scrubland (gorse, manuka)	
Keywords: Interception; Stemflow; Throughfall	

Comment
Gives data as regression relationships for a number of New Zealand sites, both Water and Soil Division projects and published data (Aldridge 1968; Aldridge & Jackson 1968, 1973; Fahey 1964; Jackson & Aldridge 1973; Rowe 1975). The assumption is that these are storm-based but this needs to be verified by looking at the original studies, where possible.

The Water & Soil Division data are an update of Blake (1972):

Trounson Park, Northland—kauri forest

throughfall	= − 0.60 × precipitation − 3.71	r = 0.971
stemflow	= 0.04 × precipitation − 0.15	r = 0.938
interception loss	= 0.43 × precipitation + 1.01	r = 0.877

Puketurua Basin, Northland.—Manuka—storms > 4 mm.

throughfall	= − 0.44 × precipitation − 0.10	r = 0.973
stemflow	= 0.38 × precipitation − 0.01	r = 0.971
interception loss	= 0.18 × precipitation + 0.1.19	r = 0.877

Whakarewarewa, Rotorua—*P. radiata* planted 1948

throughfall	= − 0.71 × precipitation − 0.66	r = 0.988
stemflow	= 0.07 × precipitation − 0.19	r = 0.948
interception loss	= 0.20 × precipitation + 0.94	r = 0.801

Whakarewarewa, Rotorua—*P. radiata* planted 1968

throughfall	= − 0.84 × precipitation − 3.21	r = 0.984
stemflow	= 0.17 × precipitation − 0.52	r = 0.950
interception loss	= 0.23 × precipitation + 0.05	r = 0.893

Otutira, Taupo—regenerating native forest

throughfall	= − 0.47 × precipitation − 0.09	r = 0.989
stemflow	= 0.30 × precipitation − 0.56	r = 0.969
interception loss	= 0.14 × precipitation + 0.66	r = 0.857

Moutere, Nelson—gorse

throughfall	= − 0.59 × precipitation − 1.88	r = 0.990
stemflow	= 0.07 × precipitation − 0.28	r = 0.929
interception loss	= 0.33 × precipitation + 2.57	r = 0.971

Attempted to give an estimate for interception by tussock grassland using artificial wetting techniques.

Blake, G.J.; Carlile, H.A. 1972: Assessing the effect of landuse changes on water yield. New Zealand Hydrological Society Symposium, Hamilton 1972. (Unpublished)

Country: New Zealand	Report Location:
Vegetation: Mixed	
Keywords: Water balance	

Comment
Attempts to carry out a water balance for the Buller catchment given a number of potential landuse change scenarios. Provides the method but no results in this manuscript.

Boomsma, D.B.; Hunter, I.R. 1990: Effects of water, nutrients and their interactions on tree growth, and plantation forest management practices in Australasia: a review. Forest Ecology and Management 30: 455–476.

Country: New Zealand, Australia	Report Location: R78
Vegetation: *P. radiata*	
Keywords: Review; Tree growth	

CAB Abstracts AN91064869/Authors' abstract

The amount and distribution of rainfall throughout the year is used to highlight climatic differences between Australia and New Zealand. Plantation forest growth (predominantly *P. radiata*) is strongly influenced by both available moisture and nutrients. Practices such as cultivation and mounding (bedding) are used on wet sites, whereas cultivation, ripping, weed control, mulching and heavier thinning regimes are recommended for dry sites.

Management of nutrients to improve growth includes some of the practices listed above, which enhance moisture relationships. Nutrient conservation measures and selection of planting stock with better root systems to explore the soil are suggested as methods to improve growth, along with direct application of nutrients in fertiliser, sewage effluents and wastes.

Responses to a questionnaire distributed to the major forestry enterprises in Australasia showed that practices with very conspicuous benefits (e.g., weed control) had generally been accepted, but the lead-time for implementation of positive research and development was still excessive. A number of other promising practices (e.g., mycorrhizal inoculation of nurseries) had only received minimal or at best a moderate acceptance by managers.

In reviewing the positive effect of recent research on management practices, it is suggested that more information on the interaction of moisture availability and nutrition along with detailed research on both positive and negative effects of cultivation is required. Potential benefits from use of wastes and effluents within forests to supply both water and nutrients will ensure the development of this practice. Experiments should be designed to explore the interactions between genetically improved stock, sites and cultural treatments, as well as physiological processes determining growth.

Comment

Useful information on distribution of plantations and requirements for successful growth.

Brownlie, R.K.; Kelliher, F.M. 1989: Puruki forest climate. Measurement techniques. Data base. Preliminary analyses. New Zealand Forest Research Institute-Bulletin No. 147. 48 pp.

Country: New Zealand	Report Location: R1571
Vegetation: Native evergreen forest; Pasture; *P. radiata*	
Land-Use Change: Afforestation	
Keywords: Tree growth	

CAB Abstracts AN 910647288

A meteorological database was constructed from measurements made in the Puruki-Rua subcatchment of the Purukohukohu Experimental Basin, New Zealand, between 1976 and 1987. Between 1986 and 1978 the vegetation changed from tall coarse pasture with widely spaced *P. radiata* seedlings to a closed canopy forest. The trees were thinned and pruned in 1980, with canopy closure being obtained again in 1983. Measurement techniques and data processing and retrieval are described.

Comment
Provides forest stand information relevant to the hydrological studies made by others.

Calder, I.R. 1996: Water use by forests at the plot and catchment scale. Commonwealth Forestry Review 75: 19–30

Country: New Zealand	Duration: 18 yr	Report Location: R85
Vegetation: Native grassland; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −3 to +14 yr		
Keywords: Water yield		

Comment
Presents the results of using an Institute of Hydrology, U.K., model to predict the changes in flow that were observed as a result of afforestation of tussock grassland at the Glendhu catchments.

Cameron. C.S.; Murray, D.L.; Fahey, B.D.; Jackson. R.M.; Kelliher, F.M.; Fisher, G.W. 1997: Fog deposition in a tall tussock grassland, South Island, New Zealand. Journal of Hydrology 193: 363–376.

Country: New Zealand	Duration: 4 months	Report Location: LKR
Vegetation: Native grassland		
Keywords: Fog; Water yield		

Comment
Swampy Summit, near Dunedin—lysimeter study.

Found median deposition rates of 0.05 mm/hr. Concluded that “changing land use from tall tussock to pastoral agriculture with short vegetation is unlikely to alter streamflows via the cloud deposition process.”

Campbell, D.I. 1989: Energy balance and transpiration from tussock grassland in New Zealand. Boundary-Layer Meteorology 46: 133–152.

Country: New Zealand	Duration: 1 summer	Report Location: LKR
Vegetation: Native grassland		

Keywords: Transpiration

Comment
Transpiration was measured on a recording lysimeter at Glendhu.
Maximum summer transpiration rates in the afternoons were 0.21 to 0.43 mm/hour. No daily data presented.

Campbell, D.I.; Murray, D.L. 1990: Water balance of snow tussock grassland in New Zealand. Journal of Hydrology 118: 229–245.

Country: New Zealand	Duration: 16 months	Report Location: LKR
Vegetation: Native grassland		
Keywords: Dew; Fog; Transpiration; Water balance		

Comment
Measurements were made using a recording lysimeter at Glendhu.
20 dew events were identified and in all of these the lysimeter lost weight indicating that condensation was not recorded as a weight gain.
41 of 249 events may have contributed fog interception—the total was about 1% of precipitation.
Mean daily transpiration rates for dry days ranged between 0.6 mm/day in June (in winter do not exceed 1 mm/day) to 3.3 mm/day in January (2–3 mm/day was typical in summer).

Interception storage capacity 0.51 mm in winter and 0.58 mm in summer. Interception loss was 21.3% of precipitation.

1 year water balance (mm):
Precipitation = Transpiration + Interception + (change in storage + drainage)
1042400 222 420

Claridge, G.G.C. 1970: Studies in element balances in a small catchment at Taita, New Zealand. International Association of Hydrological Sciences Publication No. 96: 523–540.

Country: New Zealand	Duration: 10 months	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Water quality; Water yield		

Comment
Taita native forest catchment; 4.36 ha; sampled 1 April 1969 through 12 February 1970
A paper on streamwater chemistry but gives flow totals for sampling periods.
For the full period: precipitation 780 mm; streamflow 67 mm.

Cooper, A.B.; Thomsen, C.E. 1988: Nitrogen and phosphorus in streamwaters from adjacent

pasture, pine, and native forest catchments. New Zealand Journal of Marine and Freshwater Research 22: 279–291.

Country: New Zealand	Duration: 2 yr	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; *P. radiata*		
Stand Type: Plantation 10–11 yr	Stand Density: 550/275 SPH	
Keywords: Water quality; Water yield.		

Comment
Primarily a paper on water quality of streams draining three differing land uses at Purukohukohu catchments in the central North Island. Does contain limited water balance information. Storm flow yields lowest under native forest but total yield lowest under pine.

Streamflow summary

	1983			1984		
	Pasture	Pine	Native forest	Pasture	Pine	Native forest
PTTN (mm)	1492	1437	1676	1468	1467	1556
Storm flow (mm)**	319	120	69	162	45	18
Base flow (mm)	259	146	296	280	170	282
Quickflow (mm)	147	67	21	40	14	2
Total flow (mm)	578	266	355	442	215	300

** Storm flow determined by Hewlett & Hibbert (1967) separation.

Dell, P.M. 1982: The effect of afforestation on the water resources of the Mamaku Plateau region. MSc Thesis, University of Waikato.

Country: New Zealand	Duration: 3 yr	Report Location: R1574
Vegetation: Native evergreen forest; Pasture; *P. radiata*		
Stand Type: Plantations vary up to 10 yr		
Keywords: Storm flow; Water yield		

Comment
Presents rainfall and runoff totals for catchments in the Mamaku Plateau. Geology—ignimbrites in which the jointing controls drainage. Flow is extremely variable

	1979–80		1980–81		1981–82	
	PTTN	SF mm (%)	PTTN	SF mm (%)	PTTN	SF mm (%)
Native forest	2712	1342(50)	2050	1103(54)	2350	1175(50)
Exotic forest	2268	476(21)	1872	422(23)	1743	387(19)
Exotic+native	2227	301(14)	1820	290(16)	1485	295(20)
Pasture (66%) + forest (34%)	1880	1309(69)	1458	1079(74)	1650	1039(63)

There are questions over the geological influences on springs/groundwater flows disappearing and reappearing in the catchments. Noted that as well as for total flows, quickflow (very small) and peak flows could not be related to the differing vegetation types. Each catchment's top 10 flows were similar.

Dons, A. 1980: Purukohukohu land use basin—a report on the effects of afforestation on water yield. New Zealand Hydrological Society Symposium 1980. (Unpublished).

Country: New Zealand	Duration: 11 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −4 to +6 yr	Stand Density: Various	
Keywords: Water yield		

Comment

Shows in figures the change in annual and seasonal water yield at Puruki determined by regression relationship from a pasture control catchment. Decreases started as early as the year after release spraying the pasture and planting the *P. radiata* seedlings (a reflection of the recovery of the grass—LKR).

By year 5, the annual reduction was as much as 2 L/s (44%). Winter reductions were 4 L/s (20%) and in summer were less than 2L/s but 70% of flow.

Dons, A. 1981: Results from the Purukohukohu land-use basin and their application to water and soil management. In: Waters of the Waikato. University of Waikato. Pp. 43–62.

Country: New Zealand	Duration: 11 yr	Report Location: R1575
Vegetation: Native evergreen forest; Pasture; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −4 to +7 yr	Stand Density: Various	
Keywords: Storm flow; Water yield		

Author's Abstract

The Purukohukohu land-use basin, situated midway between Rotorua and Taupo is described, together with an outline of some results concerning the hydrological effect of afforestation of pasture. After 7 yr of tree growth there have been substantial reductions in the annual, seasonal and peak flows from the small afforested catchment, which indicate beneficial effects of afforestation on gully erosion, sheet erosion and soil creep but detrimental effects on summer water supply and pollution dilution.

Comment

Planted 1973 at 2450 SPH but there had been vigorous regrowth of grasses and weeds. Thinning began April 1979 with the eastern subcatchment down to 550 SPH and pruned to 2 m. Central subcatchment was similarly treated in May 1980.

Flow reduction 7 yr after planting was 4.5 L/s = 47% of the predicted yield = 410 mm of ~1700 mm 1980 rainfall. Winter showed the greatest absolute decrease but summer the greatest proportional decrease.

Peak flows (based on those from the control catchment that were greater that 44 L/s/ha) had decreased by 90% by 1978, and after thinning in 1980 by 70%.

Dons, A. 1985: The effect of large-scale afforestation on Tarawera River flows. New Zealand Hydrological Society Symposium, Christchurch 1985. (Unpublished).

Country: New Zealand	Duration: 17 yr	Report Location: LKR
Vegetation: *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation—variable ages		
Keywords: Water yield		

Comment

Over 250 km^2 of the Tarawera catchment (906 km^2) in the central North island, New Zealand, was planted in pine forest between 1964 and 1981. This change has affected flow of the River Tarawera. Between 1964 and 1981 annual, summer and winter Tarawera flows showed significant reductions of 10.9 m^3/s, 11.4 m^3/s and 9.6 m^3/s respectively. Simple flow models for the Tarawera, and two neighbouring catchments that had undergone little land-use change, showed that about 4.5 m^3/s of these reductions, 13% of the mean flow over the calibration period, could be attributed to afforestation, while the remainder was due to decreased rainfall. The reduction attributed to afforestation was in accord with the results of small catchment studies.

Does not show data.

Dons, A. 1986: The effect of large-scale afforestation on Tarawera River flows. Journal of Hydrology (New Zealand) 25: 61–73.

Country: New Zealand	Duration: 17 yr	Report Location: LKR
Vegetation: *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation—variable ages		
Keywords: Water yield		

Author's Abstract

Over 250 km^2 of the Tarawera catchment (906 km^2) in the central North island, New Zealand, was planted in pine forest between 1964 and 1981. This change has affected flow of the River Tarawera. Between 1964 and 1981 annual, summer and winter Tarawera flows showed significant reductions of 10.9 m^3/s, 11.4 m^3/s and 9.6 m^3/s respectively. Simple flow models for the Tarawera, and two neighbouring catchments that had undergone little land-use change, showed that about 4.5 m^3/s of these reductions, 13% of the mean flow over the calibration period, could be attributed to afforestation, while the remainder was due to decreased rainfall. The reduction attributed to afforestation was in accord with the results of small catchment studies.

Comment

The only large scale study of land-use change in New Zealand. Afforestation has taken place between 1964 and 1981. Streamflow records were available for comparison for up to 15 yr pre-planting.

Dons, A. 1987: Hydrology and sediment regime of a pasture, native forest, and pine forest catchment in the Central North Island, New Zealand. New Zealand Journal of Forestry Science 17: 161–178.

Country: New Zealand	Duration: 3 yr	Report Location: R9
Vegetation: Native evergreen forest; Pasture; *P. radiata*		
Stand Type: Plantation 8 to10 yr	Stand Density: 640 SPH	
Height: 13 m		Rainfall: 1550 mm/yr
Keywords: Low flow; Storm flow; Water balance; Water yield		

CAB Abstracts AN 900646468/Author's Abstract

The hydrology and sediment regime of a 0.10-km^2 pasture, 0.34-km^2 pine (*P. radiata*) forest, and 0.28-km^2 native (podocarp/broadleaved) forest catchment were compared. The highly permeable pumice soils of these catchments resulted in generally low annual stormflow yields (0.54–5.2% of gross rainfall) and consequently low annual sediment yields (4.0–27.0 t/km^2 p.a.). The pasture catchment had the highest average flows, highest peak flow rates, and greatest stormflow yields, but lowest evaporative losses. The pasture catchment also recorded the maximum instantaneous sediment concentrations and the maximum instantaneous sediment discharges. The pine forest catchment had the lowest annual average flows, lowest low flows, and lowest instantaneous sediment concentrations and discharges, but evaporative losses were similar to those from the native forest catchment. The native forest catchment had the lowest stormflow yields, lowest peak flows, and highest low flows. Some of the differences in hydrologic responses from the native forest catchment could be explained by drainage density rather than land use.

Comment

Puruki at Purukohukohu. Closed canopy by 1981.

Some problems with delineating catchment boundaries in this volcanic terrain. There is some doubt over the area of pasture catchment as it has been adjusted to 44% of the topographic area to meet similar RO/RF ratios for other pasture catchments for estimating water yields, but not for storm flows. It should be noted that in this region, streamflows are extremely variable in proportion to rainfall as the pumice country surface topography may bear little relationship to the hydrologic boundaries with transfers from catchment to catchment—there is evidence for fractured basement rock in the pasture catchment.

There are no comparable data given in this study for the pre-planting period to enable changes in the regimes to be estimated/compared. It is a straight comparison between differing land uses.

Interception loss assumed to be 26% (unpublished data). From flow duration curves, afforestation of a pasture catchment appears to have resulted in lower peak flows and low flows—a result of increased interception and decreased net rainfall. Storm flows were 2.2% and 5% of rainfall for the pine and pasture catchments, respectively.

Water balance—mean of 3 yr

	Pasture	Pine	Native forest
Area (ha)	10*	34	28

Pttn (mm)	1427	1398	1484
Storm flow (mm) (H&H)**	74 (5.2%)	31(2.2%)	8 (0.54%)
Delayed flow (mm)	469	223	331
Total flow (mm)	543	254	339
Evapotranspiration (mm)	784	1044	1045
Groundwater loss (mm)	100	100	100
Interception***	N/A	0.26 × P = 365 mm	0.26 × P = 385 mm

* Problems with delineating the catchment hydrologic boundary
** Hewlett & Hibbert (1967) separation; Values in parentheses are percentages of precipitation
*** Interception by pine from unpublished data (New Zealand Forest Research Institute) and assumed to be the same for native forest.

Duncan, M.J. 1980: The impact of afforestation on small catchment hydrology in Moutere Hills, Nelson. *In*: Land use in relation to water quantity and quality. Nelson Catchment Board, Nelson. Pp. 61–90.

Country: New Zealand	Duration: 15 yr	Report Location: R1479
Vegetation: Pasture; *P. radiata*; Scrubland (Gorse)		
Land-Use Change: Afforestation		
Stand Type: Plantation −7 to 8 yr	Stand Density: Various	Rainfall: 1105 mm
Keywords: Interception; Low flow; Stemflow; Storm flow; Throughfall; Water yield		

Author's Abstract
.... In 1970 *P. radiata* were planted:
(a) directly on a pasture catchment
(b) in another catchment after gorse was burnt and linedozed, and
(c) in a further catchment after gorse was burnt, later disced and 9 months had elapsed.
Three control catchments remained in pasture in 1963–78.

For the12 months following burning there was an increase of 53% (184 mm) and 167% (236 mm) from the catchments previously in gorse (b and c above, respectively) and increase flow persisted 3 and 5 yr after planting respectively. There was no increase from the pasture after planting. However, by 1978 the runoff from the two catchments previously on gorse had reduced by 65% (64 mm) and 5% (2 mm) respectively, and from the catchment previously in pasture had reduced by 76% (56 mm).

The mean runoff from the three pine catchments was compared with the mean runoff from the three pasture catchments on a quarterly basis over the period 1973 to 1978 and the runoff from the pine catchments was almost invariably less than half that from pasture catchments. The greatest difference in runoff between pines and pasture catchments occurred in the July–September quarters because most runoff occurs then. However, when this difference is expressed as a percentage of runoff from pasture catchments, the greatest percentage difference occurs in other quarters.

During 1975 and 1976 there was no difference in the number of days of zero flow, but in 1977

and 1978 there was no flow from pine catchments for 2½ and 1 month, respectively, while there was still flow from the pasture catchments. For most of the low flow period runoff from pine catchments was half that from pasture.

Flood peaks and volumes from the pine catchments in 1978 were on average 73% lower than those from pasture catchments. Flood peaks from gorse catchments before they were burnt (1968 and 1969) were on average 78% lower than those from the pasture catchments. In the same years, flood peaks from the pasture catchments that were later planted in pines were 9% greater that the average from the other pasture catchments. Thus the gorse and pine reduced flood peaks by a similar amount.

Precipitation gauges under the pine canopy show that the difference between runoff from pine and pasture catchments is equal to the amount of precipitation intercepted by the pine trees.

Comment
Same catchments as in Duncan (1995a,b) with the addition of catchment 15, another pasture catchment. Covers seasonal runoff, flood peaks, low flow, and interception (including changes due to thinning)

An interception study was located in catchment 14: Planted after pasture disced in1970 at 1500 SPH; thinned 1975 (5-yr-old trees) to 500 SPH and pruned to 2.5 m. Canopy closure by 1978

Pre-thinning (5-yr-old trees)	IL = 20% of PTTN (= 220 mm of MAP)
Post-thinning	IL = 8% of PTTN = 60% reduction in IL for 60% reduction in stem numbers.

Data below is off Figure 15 for trees up to aged 8 yr

Moutere catchment 14 interception data

Age	TF%	SF%	IL%
4	86	5	9
5 Pre-thinning	74	3	23
5 Post thinning	88	3	9
6	83	3	14
7	80	3	17
8	76	4	20

Duncan, M.J. 1983: The effects of planting pines on water yield in Nelson. New Zealand Hydrological Society Symposium, Dunedin, 1983. (Unpublished).

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*; Scrubland (Gorse)		

Land-Use Change: Afforestation		
Stand Type: Plantation −7 to 11 yr	Stand Density: Various	Rainfall: 1105 mm
Keywords: Low flow; Storm flow; Water yield		

Comment
Moutere, Nelson. An update of Duncan (1980) with an additional 3 yr of data.

In 1970 *P. radiata* were planted:
(a) directly on a pasture catchment
(b) in another catchment after gorse was burnt and linedozed, and
(c) in a further catchment after gorse was burnt, later disced and 9 months had elapsed.
Three control catchments remained in pasture in 1963–81.

Since 1978 water use by the pines had leveled off. By 1981, runoff reduction from the two catchments previously in gorse, 51% and 2%, and from the one previously in pasture, 60%, were smaller than given in Duncan (1980).

Notes that for 1975–1981 the seasonal yield from the pine catchments was invariably less than half that from the pasture catchment, the magnitude being greater in the July–September quarter when flow is greatest but other quarters had the greatest percentage change.

Five and 6 years after planting there was no difference in the number of days of zero flow in the pine and pasture catchments. For the years 8 to 11 after planting, there were 82 days with no flow in the pine and pasture catchments with an extra 52 days without flow in the pine catchments.

Between 1978 and 1981, flood peaks and quickflow volumes from the pine catchments were only 27% and 14% of that from the pasture catchment. Notes that before being burned, flood peaks in the gorse catchments were 22% of those in the pasture catchment, a similar effect to that of the pines.

Duncan, M.J. 1993: Does planting pines reduce groundwater recharge? New Zealand Hydrological Society Symposium, Nelson, 1993. (Unpublished).

Country: New Zealand	Duration: 11 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*; Scrubland (Gorse)		

Land-Use Change: Afforestation		
Stand Type: Plantation 4–15 yr	Stand Density: Various	Rainfall: 1105 mm
Keywords: Soil water		

Comment
Moutere catchments, Nelson.
Monitored soils moisture from 1974 (trees age 4 yr) to 1986. Used a neutron probe and had three access tubes in each of the pasture and two pine catchments.

There were no data from the pretreatment period or for the first 4 yr of tree growth so the reference point was 1974. Soil moisture from the pines catchment 8 was always below that of the pasture, got larger until age 6 yr and tended to remain at a constant lower level thereafter. In pines catchment 14, the soil moisture deficits were similar at the start of the sampling period and declined up until year 7 to a constant deficit except for marked responses to thinning.

A plot of mean monthly soil water potential deficits for 1974–1986 shows the pine catchments to be in deficit longer (December to June compared to February to May) and by a greater amount. When there was a surplus, that in the pines was smaller than for the pasture catchment.

Duncan, M.J. 1995a: Hydrological impacts of converting pasture and gorse to pine plantation, and forest harvesting, Nelson, New Zealand. Journal of Hydrology (New Zealand) 34: 15–41.

Country: New Zealand	Duration: 28 yr	Report Location: R30
Vegetation: Pasture; *P. radiata*; Scrubland (gorse)		
Land-Use Change: Afforestation		
Stand Type: Plantation −7 to 20 yr	Stand Density: Various	Rainfall: 1018 mm
Keywords: Interception; Low flow; Stemflow; Storm flow; Throughfall; Water yield		

CAB Abstracts AN 950619305/Author's Abstract

The hydrological impacts of converting hill country pasture and tall dense gorse [*Ulex europaeus*] to *P. radiata* plantation and subsequent felling of the mature forest are examined using data collected from five small (4.0–7.7 ha) catchments in Moutere Gravel hill country near Brightwater, Nelson, New Zealand. After a 6-yr calibration period one pasture catchment and two tall dense mature gorse catchments were planted at a density of 1500 trees/ha in 1970/71. The trees were pruned and thinned at various times until in 1981 all catchments were stocked at 300 trees/ha. The trees were felled in the winter of 1991. Annual water yield increased by 219–358 mm/yr in the 3 yr after the gorse catchments were cultivated or line dozed for planting. Water yield reduced to preplanting values 4–5 yr after planting. Over the next 2–3 yr annual water yield continued to decline, as the canopy closed. Thereafter annual water yields were relatively constant with some response to annual rainfall variation and silvicultural practices. These water yields averaged 63 mm/yr less than would be expected from gorse. Water yields in the former pasture catchment started to reduce 3 yr after planting and beyond 7 yr averaged 167 mm/yr less than expected from pasture. Four months after clear-felling, when soil moisture levels had been replenished, runoff rates had increased and were greater than those from pasture. In the first and second years after harvest flows

increased 0–60 mm/yr and 226–343 mm/yr, respectively, above those expected from *P. radiata*, to yield in the second year flows similar to those expected from bare land.

The small catchments were all ephemeral, and those with gorse or *P. radiata* cover can be expected to be dry for 3 months per year more than pasture catchments. When all catchments are flowing, *P. radiata* or gorse catchments have less than half the flow expected from pasture catchments.

Peaks of freshes from *P. radiata*/gorse catchments are 20% of those from pasture catchments. As annual flood exceedance probability (AEP) decreases the difference in flood size also decreases until for AEPs of 0.02 flood peaks from *P. radiata*/gorse catchment average half of those from pasture catchments. The differences in runoff between *P. radiata* and pasture catchments are primarily attributed to greater interception by the *P. radiata* trees and greater soil moisture storage potential under *P. radiata* because of their greater rooting depth.

Comment

Moutere: study covers a full rotation although there are a couple of gaps in the record. Pines were planted in land from pasture or gorse. MAP 1018 mm, and ranges from 53 mm in February to 103 mm in August.

Runoff for various periods

Period	Rainfall (mm)	C2 pasture	C5 pasture	C8 pines x gorse	C13 pines x gorse	C14 pines x pasture
Control 1964–1970	1032	258	284	242	128	258
1971–1975	1013	203	278	378	228	172
1976–1981	986	158	213	67	56	40
1982–1987	1015	223	289	108	87	57
1991/92–1992/93	989		216	298	148	136

Interception data

Post-thinning here is after the second thinning when the trees were reduced to 300 SPH March1981, Moutere C14 x Table 3

First thinning/pruning period was July 1975 to 500 SPH

Throughfall data from Moutere C14 pines

Year	Age (yr)	PTTN (mm)	C14 IL Pre-thinning (mm (%))	C14 IL Post-thinning (mm (%))
1975	4	1167	130 (11)	
1976	5	1300	307 (24)	
1977	6	963	177 (18)	
1978	7	855	236 (28)	

1979	8	1028	284 (28)	
1980	9	1082	491 (45)	
1981	10	938		134 (14)
1982	11	834		183 (22)
1983	12	1284		179 (14)
1984	13	1027		273 (27)
1985	14	1214		259 (21)

Seasonal effect: IL Autumn 24% Winter 27% Spring 20% Summer 18%. Note: this trend is opposite to Donald Creek, South Nelson, data for native evergreen forest (Rowe 1985).
Stemflow 5.5% for 1500 SPH, 3.1% for 500 SPH, and 0.1% for 300 SPH.

Duncan, M.J. 1995b: Predicting the effects of afforestation on low flows in the Mangakahia catchment, Northland. New Zealand Meteorological and Hydrological Symposium, November 1995, Christchurch. 2 p. (Unpublished).

Country: New Zealand	Duration: 14 yr	Report Location: LKR
Vegetation: Mixed; Pasture; *P. radiata*		
Land-Use Change: Afforestation (pasture/scrub)		
Keywords: Low flow		

Comment
Mangakahia above Titoki—809 km^2. Between 1980 and 1995, 24% underwent afforestation from undeveloped pasture and scrub to *P. radiata*—mostly before 1988.

To quote:

"An annual low flow series (1982–1995) without pines was constructed by increasing flow on a pro-rata basis based on the area of pines and the original vegetation and the percentage change in flow associated with that landuse change. Minimum series were constructed in a similar way on the basis of the current level of pine planting and/or future predicted levels of pine planting to give a list of estimated mean annual minima from catchments with current and predicted areas of pine forest.

Flow has been measured at Mangakahia at Gorge site since 1961 and not until 1983 could the flows have been affected by converting catchment cover to pines. The mean annual low flow 1961–1982 was 1447 L/s and for 1983–1995 was 10.3% less at 1298 L/s. Annual rainfall data indicates that rainfall differences between the periods are unlikely to be the cause of this reduction in minima. Calculation of the minima since planting based on the area and landuse of land converted to pines and the New Zealand wide average hydrological effects of those changes, estimates the 1983–1995 mean annual low flow to be 1315 L/s (9/1% less than the pre-planting minima of 1447 L/s). This estimate is close to(17 L/s different) the measured mean annual minima for the same period."

Egunjobi, J.K. 1971: Ecosystem processes in a stand of *Ulex europaeus* L. II. The cycling of chemical elements in the ecosystem. Journal of Ecology 59: 669–678.

Country: New Zealand	Duration: 15 months	Report Location: LKR
Vegetation: Scrubland (Gorse)		
Keywords: Throughfall		

Comment
No information on the stand is presented in this paper.

Throughfall under gorse

Month	Precipitation (mm)	Throughfall (mm)
Apr 1966	205	62
May	212	64
Jun	118	27
Jul	165	50
Aug	154	46
Sep	96	27
Oct	55	10
Nov	111	27
Dec 1966	248	61
Jan1967	101	35
Feb	100	37
Mar	106	39
Apr	108	34
May	91	23
Jun 1967	77	23
Total	1519	565 (37%)

Fahey, B.D. 1964: Throughfall and interception of rainfall in a stand of radiata pine. Journal of Hydrology (New Zealand) 3: 17–26.

Country: New Zealand	Duration: 9 months	Report Location: R226
Vegetation: *P. radiata*		
Stand Type: Plantation—30 yr	Stand Density: 340 SPH	
Height: 21 m	Diameter: 25 cm	
Keywords: Interception; Throughfall		

Author Abstract

Some interception values are determined for *P. radiata* in the Silverstream catchment, Otago. Both net rainfall and pattern of throughfall are correlated with a number of factors. Individual storm total appears to be the main factor in determination of throughfall and interception loss.

Over the 9-month recording period a total rainfall of 920 mm was measured in the open. Of this total, on the average, only 48% (440 mm) reached the forest floor as throughfall; 49% (450 mm) being attributed to the average interception loss. Stemflow was accounted for by the 3% (30 mm estimate) deficit.

Comment

Throughfall was higher in storms with no wind, and in larger rainfall events.

Throughfall and interception loss with storm size

Storm size (mm)	Throughfall %	Interception loss %
0–2.5	22	78
2.6–7.6	40	60
7.7–19.8	54	46
19.9–32.8	56	44
37.5–85.6	62	38

Fahey, B.D. 1990: Hydrological impacts of afforestation of tussock grasslands, Glendhu Forest, Otago. New Zealand Hydrological Society Symposium, Taupo 1990. (Unpublished).

Country: New Zealand	Duration: 10 yr	Report Location: LKR
Vegetation: Native grassland; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −2 to 7 yr	Rainfall: MAP 1350 mm/yr	
Keywords: Storm flow; Water yield;		

Comment

Describes the Glendhu catchments and treatments. In the first 6 yr after planting 67% of GH2, the only hydrological change noticed was a reduction in the proportion of quickflow. From about 6 yr after planting, monthly streamflow yields from GH2 were less than from the control catchment in tussock grassland amounting to a reduction of about 130 mm/yr or 25% of the flow.

Peak flows were reduced in the 7th year. For the flow class 5–10 L/s/ha, the average peak flow from the planted catchment was 50% lower than from the tussock catchment compared to 7% less in the pretreatment period. A smaller reduction was noted in the flow class > 10 L/s/ha, 22% compared to 5% in the pretreatment period.

Fahey, B. 1994: The effect of plantation forestry on water yield in New Zealand. New Zealand Forestry 39: 18–23.

Country: New Zealand	Duration:	Report Location: R35
Vegetation: Native evergreen forest; Native grassland; Pasture; *P. radiata*; Scrubland		
Land-Use Change: Afforestation; Conversion from native forest; Forest management; Harvesting		
Stand Type: Plantation ages vary		
Keywords: Low flow; Review; Storm flow; Water yield		

CAB Abstracts AN 950606094

Author Abstract

This paper discusses the hydrological consequences of converting land in native forest, scrub, tussock grassland, and pasture to plantation forestry, and the impacts of harvesting and re-establishing a tree crop. Forests influence water yield and associated streamflow responses through increased canopy interception of rainfall. Thus afforestation of pasture may reduce water yield by 30–50% 5–10 yr after planting. For tussock grasslands the reduction is between 25 and 30%. A similar percentage reduction can be expected in low flows. Storm quickflows and flood peaks can fall by over 50%. Silvicultural practices, such as understorey control and spreading the time of planting, have the potential to augment water yield.

Forest harvesting in moderate-to-high rainfall areas can cause a 60–80% increase in water yield for 3–5 yr after clearfelling. Yields should return to pre-harvesting levels within 6–8 yr, depending on the silvicultural regime adopted. Mean flood peaks can rise by up to 50%. However, the hydrological impact must be viewed within the context of the area harvested compared with the total forest area. If the former is small in comparison, any local increases in water yield and flood response may be quickly attenuated.

Comment

Reviews a number of New Zealand studies discussed elsewhere here.

Fahey, B.D. 1999: Interception loss by stands of Douglas fir and radiata pine near Hororata, Mid-Canterbury. New Zealand Hydrological Society Symposium, Napier 1999. (Unpublished).

Country: New Zealand	Duration: 9 months	Report Location: LKR
Vegetation: Douglas fir; *P. radiata*		
Stand Type: Plantation: 17 yr		
Keywords: Interception; Stemflow; Throughfall		

Comment

Interception by *P. radiata* and Douglas fir stands

	P. radiata 17 yr	Douglas fir 18 yr	Douglas fir 54 yr
Stand density (SPH)	654	1360	570
Rainfall (mm)	712	712	648
Throughfall (mm)	495	455	399
Stemflow (mm)	55	32	33
Interception loss (%)	23	33	34

Fahey, B.D. 2000: Interception loss by stands of Douglas fir and radiata pine, South Island, New Zealand. IUFRO World Congress 2000, August 2000, Kuala Lumpur. Forests and Society: The Role of Research. Poster Abstracts Vol. 3: 454–455.

Country: New Zealand	Duration: 9 months	Report Location: LKR
Vegetation: Douglas fir; *P. radiata*		
Stand Type: Plantation: 17 yr		
Keywords: Interception		

Comment
Rainfall for the 9 months was 700 mm.

Interception loss for *P. radiata* and Douglas fir stands

	P. radiata 17 yr	Douglas fir 18 yr	Douglas fir 54 yr
Stand density (SPH)	654	1360	570
Interception loss (%)	23	33	34

Fahey, B.; Jackson, R. 1995: Hydrological effects of converting indigenous forests and grasslands to pine plantations, Big Bush and Glendhu experimental catchments. New Zealand Meteorological and Hydrological Symposium, Christchurch 1995. (Unpublished).

Country: New Zealand	Duration: 13/15 yr	Report Location: LKR
Vegetation: Native evergreen forest; Native grassland; *P. radiata*		
Land-Use Change: Afforestation; Conversion from one forest to another		
Stand Type: Plantation −2 to 10 yr		
Keywords: Low flow; Storm flow; Water yield		

Comment

Big Bush Forest, Nelson.
In the 4 yr after harvesting native forest in two catchments, average annual yields increased by 310 (61%)and 342 (68%). Peak flows in all storm classes increased after harvesting: 2–5 L/s/ha by 77% and 52%; 8–15 L/s/ha by 16% and 0%. Quickflows responded similarly but were more subdued. Yields were back at pretreatment levels after 8 yr, this being delayed by increases after thinning operations. Storm peak flows and quickflows took 10 yr to return to pretreatment levels. In the 5 yr after harvest, lowflows were 2–3 times that of the control catchment but had returned to pretreatment levels after 5 yr.
Glendhu, Otago—67% planted.
There was no difference in yield for the 6 yr after planting a tussock catchment. In the 8–12 year period after planting yields were reduced by 231 mm (27% of the runoff at the control catchment. The mean minimum 7-day low flows showed a reduction of 0.18 mm/day and peak flows had reduced by 55–65% depending on the flow class size.

Fahey, B.; Jackson, R. 1997a: Hydrological impacts of converting native forests and grasslands to pine plantations, South Island, New Zealand. Agricultural and Forest Meteorology 84: 69–82.

Country: New Zealand	Duration: 13/17 yr	Report Location: R32
Vegetation: Native evergreen forest; Native grassland; *P. radiata*		
Land-Use Change: Afforestation; Conversion from one forest to another		
Stand Type: Plantation −2 to 15 yr	Rainfall: Big Bush 1530 mm/yr; Glendhu 1350 mm/yr	
Keywords: Low flow; Storm flow; Water yield		

CAB Abstracts AN 970605082/Authors' Abstract

Changes in water yield, flood hydrology, and low flow caused by replacing indigenous forests and grasslands with commercial softwoods have been investigated in New Zealand since the mid-1970s. The long-term results of two of these studies are discussed here.

The first deals with the conversion of mixed evergreen forest to pine plantation in the northwestern South Island. After a 2-yr calibration period one catchment was left as the control (DC2) and the other two catchments were harvested in 1981, one by skidder (DC1) and the other by hauler (DC4), and planted in pines shortly thereafter. For the first 4 yr after harvesting the average annual difference in water yields between DC1 and DC2 was 352 mm (69%), and between DC4 and DC2 was 463 mm (90%), which equates to an annual increase of 312 mm (68%), respectively, when compared with the calibration period. Planting the harvesting areas caused the water yield from both catchments to return to pre-harvesting levels within 8 yr, and an estimated reduction in runoff of 340 mm within 5 yr at DC4. Mean flood peaks increased after harvesting, especially for small and medium storms on the skidder-logged catchment (75–100%). The response of the storm quickflows to harvesting was similar but much more subdued. Low flows also increased after harvesting. Tree growth brought storm peak flows, quickflows, and low flows back to the levels of those in the original beech forest within 10 yr.

The second study examines the impact of converting tussock grasslands to pine plantations using data collected from two catchments in the eastern uplands of southern New Zealand. After a 3-yr calibration period (1980–1982) one catchment was planted in pines over 67% of its area and the other was left in tussock. By 1989 the difference in annual water yield from the planted catchment

was 130 mm, and between 1991 and 1994 it averaged 260 mm (27% of total runoff from the control). Differences in low flows (represented by the minimum annual 7-day mean) showed a similar trend, and suggest that in dry periods, afforestation of tussock grasslands can reduce water yields by 0.18 mm/day. Higher interception losses from increased canopy evaporation is believed to be the main reason for the reduction in water yield. After 10–12 yr of tree growth mean flood peaks had fallen between 55 and 65%, and quickflows had decreased by about 50%.

Comment
Gives changes in water yields but no data on annual flows under any of the vegetation regimes.

Big Bush—Conversion of native forest to pine plantation
Low flows, peakflows and yields all increased after harvesting the native forest. In the 4 yr after 83% clearfelling of DC1 streamflow increased 312 mm/year (61%) and at the 94% cleared DC4 the yield was 344 mm/year higher (90%). (These are proportionally equivalent to 375 and 365 mm on a 100% clearfelling basis—LKR). After this, there was a decline in flows to pre-harvest levels after about 8 yr.
Low flow comparison are difficult as DC2, the control catchment, dries up in some years. However there were increases in the 7-day minimum flow up to 0.05 mm/day at DC4 after harvesting and this had declined to native forest levels by about 10 yr after planting.

Glendhu—Afforestation of tussock grassland at GH2
Annual flows began to diminish about 5 yr after planting and seemed to approach a stable level of about 250 mm lower than the tussock catchment after about 8 yr. This was for a catchment planted over 67% of its area.
Low flows: Between 1992 and 1994, the minimum 7-day low flow at GH2 averaged 0.18mm/day lower (0.13 to 0.33 mm range); GH1 range was 0.5 to 1 mm/day in nearly all years.
Peakflows: Four size classes (> 2 L/s/ha). 1991–1993 had fewer storm at GH2 than at GH1. For comparable storms in the size classes at GH1 storms were reduced at GH2 by an average 57% in 2–5, 58% in 5–10 (15 storms), 65% in 10–15, and 55% in >15 L/s/ha size classes.
Storm quickflow: in four classes above 5 mm, mean yields were reduced 40 to 57% compared to GH1, and there were lesser events in each size class.

Fahey, B.D.; Jackson, R.J. 1997b: Environmental effects of forestry at Big Bush Forest, South Island, New Zealand: I. Changes in water chemistry. Journal of Hydrology (New Zealand) 36: 43–71.

Country: New Zealand	Duration: 7 yr	Report Location: R36
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation −2 to +5 yr		
Keywords: Water quality; Water yield		

CAB Abstract/Author abstract

This study considers short-term (immediate post-harvesting) and long-term (forest establishment) changes in water chemistry (base cations, total N, and total P) in streamflow from three experimental catchments in Big Bush Forest, central Nelson. One (DC2) has been left in beech/podocarp forest as the control (4.77 ha). In 1980 catchment DC1 (8.57 ha) was skidder-logged and DC4 (20.19 ha) was hauler-logged. In DC1, concentrations of the dominant cation (Na^+) rose from a pretreatment mean of 2.83 mg/L to a maximum of 5 mg/L, then declined to 3.82 mg/L, 4 yr after harvesting. For K^+, the pre-treatment mean concentration was 0.75 mg/L, rising to a maximum of 5.4 mg/L, but 1 yr later had fallen to a mean of 0.90 mg/L. Fluctuations in concentrations of Ca^{2+} and Mg^{2+} were smaller. Similar patterns of change were recorded at DC4. Total N concentrations at DC4 increased 10–12 times compared with the control, but seldom exceeded 1 mg/L, and were close to pretreatment levels 4 yr after harvesting. The response of total P was similar but more subdued. Cation yields over the period 1980–1986 for DC1 and DC4 were double that of the control (22.4 kg/ha/yr). Total N yields (0.18–0.44 kg/ha at the control) were much lower than those for cations. At DC4 they increased by up to an order of magnitude after harvesting, and were still 3–5 times higher than the control 4 yr later. Total P (0.08–0.14 kg/ ha/yr at the control) increased 2–3 times after harvesting. Rainfall chemistry data from other sites suggest an approximate balance between cation and nutrient inputs and outputs for undisturbed beech/podocarp forest. Recent short-term monitoring suggests that cation and nutrient yields in streamflow from pine plantations at mid-rotation will be comparable to those from mature beech/podocarp forest. Yields of total N in the first few years after harvesting were comparable to or less than those recorded for pasture.

Comment:
Shows annual water yields for the three catchments for 1980–1986 (their Fig. 2). Increase in water yield after clearfelling the native forest are apparent and this begins to decline after about 3 yr as the *P. radiata* crop grows. However, the main thrust of the paper discusses water quality changes.

Fahey, B.; Jackson, R.; Rowe, L.K. 1998a: Hydrological effects of land-use change in the upper Waipori catchment, east Otago. Meteorological Society of New Zealand and New Zealand Hydrological Society Symposium, Dunedin, 1998. (Unpublished).

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: Native grassland; Pasture; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −3 to 15 yr		
Keywords: Low flow; Water yield		

Comment
At Glendhu between 8 and 14 yr after planting 67% of a tussock catchment streamflow yields had fallen by an average of 270 mm (31%) of streamflow from the control catchment. Minimum annual 7-day low flows had fallen 0.13 mm/day, 16% of that at the control catchment.

Data from Glendhu was used in a daily water balance model to show that if the plantation area of the upper Waipori catchment was converted to pasture or returned to tussock grassland, water yields would increase by 5% and 8%,respectively.

Fahey, B.; Jackson, R.; Rowe, L.K. 1998b: Hydrological effects of afforestation and pasture improvement in montane grasslands, South Island, New Zealand. *In*: Sassa, K. (Ed.) Environmental Forest Science. Kluwer Academic Publishers. Dordrecht. P 395–404.

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: Native grassland; Pasture; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −3 to 15 yr		
Keywords: Low flow; Water yield		

Comment
At Glendhu, 7 years after planting 67% of GH2, annual streamflow had fallen by 130 mm and between 9 and 15 yr after planting yields had fallen by an average of 270 mm (31%) of streamflow from the control catchment.
Minimum annual 7-day low flows had fallen 0.11 mm/day, 15% of that at the control catchment, between 12 and 15 years after planting.
A model was used to estimate changes likely to occur if there were land use changes in the Waipori catchment—30000 ha of which 49% is in tussock grassland, 34% in pasture/depleted tussock land, 17% plantation forest. If the forest was not present, runoff would be 5% higher if the land had been originally in pasture and 8% higher if originally in tussock.

Fahey, B.; Jackson, R.; Sutcliffe, C. 1991: Effects of land-use change on water yields from Dunedin's water supply catchments. New Zealand Hydrological Society Symposium, Wellington 1991. (Unpublished).

Country: New Zealand	Report Location: LKR
Vegetation: Native grassland; Pasture	
Keywords: Water yield	

Comment
Current pastoral management has modified the original tussock cover by burning and grazing, and conversion to improved pasture. Notes that "If the tussock cover is left to return to a condition of nil depletion and vigorous growth in the key water producing areas, water yields for the three summer months in the driest year should increase by 48% and 52% at the Deep Creek and Deep Stream water intakes respectively."

Fahey, B.D.; Rowe, L.K. 1992: Land-use impacts. Ch. 15 in Mosley, M.P. (Ed.) Waters of New

Zealand. New Zealand Hydrological Society, Wellington. Pp. 265–284.

Country: New Zealand	Report Location: R1603
Vegetation: Native evergreen forest; Native grassland; Pasture; *P. radiata*; Scrubland	
Land-Use Change: Afforestation; Conversion from one forest to another	
Keywords: Review; Storm flow; Water balance; Water yield	

Comment
Reviews many of the New Zealand studies on the effects of land-use change on the hydrology of catchments.

Fahey, B.D.; Watson, A.J. 1991: Hydrological impacts of converting tussock grassland to pine plantation, Otago, New Zealand. Journal of Hydrology (New Zealand) 30: 1–15.

Country: New Zealand	Duration: 11 yr	Report Location: R31
Vegetation: Native grassland; *P. radiata*		
Land-Use Change: Afforestation		
Stand Type: Plantation −3–8 yr	Stand Density: Initially 1250 SPH	
Keywords: Low flow; Storm flow; Water balance; Water yield		

CAB abstracts AN 920662839/Authors' Abstract

The hydrological impacts were studied of converting lightly grazed mid-altitude tussock grassland to *P. radiata* plantation, using data collected from two medium-sized catchments in upland east Otago. After a 3-yr calibration period, 207 ha of one catchment (310 ha) were planted at 1250 stems/ha in 1982. No change in water yield was observed until late 1988. In 1989, annual runoff from the planted catchment was 100 mm less than that from the adjacent control tussock catchment (218 ha). The same was true in 1990, representing a 20% reduction in water yield each year. Site preparation before planting had a much earlier effect on the quickflow component of annual runoff, causing it to decrease by about 9% in 1983. The peak flow rates of small storms (<10 L/s/ha) were most affected by afforestation and showed an average reduction of up to 50% for the 1988–90 period. Storm quickflow volumes showed a 29% reduction over the same period. Flow-duration curve analysis suggested that less water is now being released as low flow storage in the planted catchment than in the control catchment. Greater interception loss through increased evaporation rates from a wetted forest canopy is believed to be the main reason for reduced water yields after almost 8 yr of tree growth.

Comment
A 200-ha tussock grassland catchment was ripped and planted with *P radiata* seedlings in 1982 after 3 yr of calibration data. 67% of the catchment was planted—riparian areas and wetlands were excluded. The decline in flow became manifest in 1987.

Water yield changes at Glendhu for 67% afforestation of GH2

Year	Precipitation (mm)	GH1 (mm)	GH2 (mm)	Difference (GH1−GH2)	Reduction (%)
1980	1555	911	907	4	1
1981	1265	728	707	21	3
1982	1482	837	825	12	1
1983	1572	1115	1145	-30	-3
1984	1388	946	883	63	7
1985	958	488	476	12	2
1986	1487	799	810	-11	-1
1987	1591	1008	959	49	5
1988	1321	718	681	37	5
1989	1222	705	574	131	19
1990	1063	533	428	105	20
Mean	1355	799	761		

Comparison between storm flows in the >10 L/s/ha size class at the control catchment showed a reduction in the planted catchment.

Low flows may be showing signs of reduction in flow.

Fahey, B.; Watson, A.; Payne, J. 2001: Water loss from plantations of Douglas fir and radiata pine on the Canterbury Plains, South Island, New Zealand. Journal of Hydrology (New Zealand) 40: 77–96.

Country: New Zealand	Duration: 20 months	Report Location: LKR
Vegetation: Douglas fir; *P. radiata*		
Keywords: Evaporation; Interception; Stemflow; Throughfall; Transpiration; Water balance		

Comment

Stand parameters and interception values, Canterbury, New Zealand

	P. radiata	Douglas fir	Douglas fir
Age (years)	18	18	54
Height (m)	20	11	28
Stocking (SPH)	650	1350	550
Mean DBH (cm)	30	19	38

Basal area (m^2/ha)	46	38	67
Sapwood area (m^2/ha)	14	14	9
Gross precipitation (mm)	1586	1586	1397
Throughfall (mm)	1195	1064	920
Throughfall (%)	75	67	66
Stemflow (mm)	90	61	70
Stemflow (%)	5.7	5	3.9
Interception loss (mm)	301	461	407
Interception loss (%)	20	29	28

In addition to the interception measurements made, eight months (October to May) of transpiration data derived from sapflow measurements are available.

Estimated water balance (mm), *P. radiata* and Douglas fir, October to May

	18-yr-old *P. radiata*	18-yr-old Douglas fir	54-yr-old Douglas fir
Gross rainfall	816	816	700
Interception	155	219	170
Transpiration	341	382	406
Understory evaporation	41	0	35
Total losses	536	601	611
Available for recharge	280	215	89

Graynoth, E. 1979: Effects of logging on stream environments and faunas in Nelson. New Zealand Journal of Marine and Freshwater Research 13: 79-109.

Country: New Zealand	Duration: 1 year	Report Location: LKR
Vegetation: Douglas fir; Native evergreen forest; Pines; *P. radiata*		
Land-Use change: Forest management		
Keywords: Water quality; Water yield		

Comment

Four catchments were studied in Golden Downs Forest, Nelson for 12 months looking at water quality and stream fauna.

Long Gully	232 ha control catchment with, in July 1973, about 58% Native evergreen forest, 31% 15-year-old Corsican pine and 11% open areas & roads.
Rough'ns Creek	2031 ha catchment with, in July 1973, about 14% Native evergreen forest, 61% *P. radiata* and Douglas fir of various ages, 25% open areas & roads.
Upper Gilbert Creek	47 ha catchment. Harvesting the native forest occurred before and during the

	study and *P. radiata* and *Eucalyptus delegatensis* were planted. In July 1973 the catchment was 38% Native evergreen forest, 0% exotic forest and 62% open areas & roads after clearfelling beech forest. A further 28% was harvested between Dec. 1973 and Feb. 1974.
Lower Gilbert Creek	185 ha catchment with, in July 1973, about 51% Native evergreen forest, 36% 1- and 2-year-old *P. radiata* and 14% open areas & roads.

Only Long Gully and Upper Gilbert Creek had recording water-level recorders.

Precipitation and Runoff from Golden Downs Catchments

	Precipitation (mm)	LG Runoff (mm)	UGC Runoff (mm)	UGC–LG (mm)
Sep 1973	77.5	46.9	51.3	4.4
Oct	76	6.1	18.1	12
Nov	199.5	99.9	122.2	22.3
Dec	106.5	13.7	30.7	17
Jan 1974	67	6.6	26.7	20.1
Feb	147.5	30.3	73.5	43.2
Mar	25	0.9	6.7	5.8
Apr	401.5	265.9	213.4	46.5
May	134.5	45.3	74.5	29.2
Jun	24.5	6.9	21	14.1
Jul	263.5	141.8	183.7	41.9
Aug	124	76.7	65.5	-11.2
Total	1647	741	986	245.3
PTTN-RO		906	661	245

These differences are between a catchment in mixed native/exotic forest and a catchment with 38% native forest and the rest recently clearfelled. There is no data presented to indicate if there are naturally occurring differences in streamflow from the 2 catchments in a fully forested state. Rainfall is measured on a ridge between the 2 catchments and it is assumed that it applies uniformly to both catchments. The difference in streamflow between the 2 catchments is attributed to the treatment effect, i.e. harvesting 62% of the native forest initially, to 90 % in the latter half of the study.

Graynoth, E. 1992: Long-term effects of logging practices in streams in Golden Downs State Forest, Nelson. *In:* Hayes, J.W.; Davis, S.F. (Eds). Proceedings of the Fisheries/ Forestry Conference, February 1990. MAF Freshwater Fisheries Centre, New Zealand Freshwater Fisheries Report No 136. Pp 52–69.

Country: New Zealand	Report Location: LKR
Vegetation: Douglas fir; Native evergreen forest; Pines; *P. radiata*	
Land-Use change: Forest management	
Stand Type: Plantation	
Keywords: Water quality; Water yield	

Comment
This is an update of Graynoth (1979) in which four catchments were studied in Golden Downs Forest, Nelson. Comparisons are made between visits in 1973–74 and January and March 1990, the 1990 visits being during a drought beginning in November 1989.

Makes a comment that in January 1990 streamflows in Long Gully, a gauged control catchment, were similar to those in 1973–1974, but observed that in Rough'ns and Gilbert Creek long sections of the streambed were dry.

Hayman, J.M.; Stocker, R.V. 1992: Soil water extraction patterns under pasture and lucerne on two soil types in Mid-Canterbury. Proceedings, Agronomy Society of New Zealand 12: 61-63.

Country: New Zealand	Report Location: LKR
Vegetation: Pasture	
Keywords: Soil water	

Comment
This paper is based on an irrigation study but provides information on soil water stores and extraction.

Lucerne extracted water down to 1.4 m from Wakanui clay loams and 1.25 m from Eyre stony silt loam with no preferential extraction throughout the profiles. In contrast, pasture preferred to extract water from the upper part of the profiles but down to 1.25 m from Wakanui soils and 0.8 m from Eyre soils.

Soil properties (% w/w)

Depth	Wakanui		Eyre	
	Field capacity	Wilting point	Field capacity	Wilting point
0–30 cm	27	11.6	15.2	7.4
0–60 cm	23.4	11.3	16.1	5.9
0–105 cm	21.8	9.4	16.5	5.5

Herald, J. 1978: The influence of afforestation in radiata pine on the runoff of a small catchment in the Hunua Ranges, Auckland. New Zealand Hydrological Society Symposium 1978. 20 p.

Country: New Zealand	Duration: 8 yr	Report Location: LKR
Vegetation: *P. radiata*; Scrubland		
Land-Use Change: Afforestation (scrub to plantation)		
Stand Type: Plantation −3 to +5 yr		
Keywords: Water yield		

Comment

Presents data for the control and *P. radiata* catchments at Hunua. This is a shorter data set than in Barton & Card (1979) and the values are slightly different—possibly adjusted for climate and wetland areas. The afforested catchment was part-cleared 1968, burnt 1970 and planted in 1971.

Precipitation and runoff for Moumoukai catchments.

Year	Precipitation (mm)	Control catchment runoff (mm)	Afforested catchment runoff (mm)	Control-afforested runoff (mm)*
1968	2162	1264	1230	36
1969	1539	846	736	110
1970	1880	1034	1058	-24
1971	2090	1287	1186	101
1972	1614	903	789	114
1973	1321	534	416	118
1974	1441	629	439	190
1975	1853	973	680	297
1976	1993	1054	671	383

* Calculated by LKR

The last column in the table indicates that flows were diminishing 3 yr after planting the pine seedlings. There are also graphs of seasonal changes in flow with time but no data are provided to verify the trends and conclusions.

Some of the adjustments made to the flow data for climate and time trends may need to be revisited.

Herald, J.R. 1979: Changes in streamflow in a small drainage basin following afforestation in radiata pine. MSc. Thesis. University of Auckland.

Country: New Zealand	Duration: 10 yr	Report Location: LKR
Vegetation: *P. radiata*; Scrubland		
Land-Use Change: Afforestation (scrub to plantation)		
Stand Type: Plantation −3 to +6 yr		
Keywords: Water yield		

Comment
Same data set as Herald (1978). Presents monthly data as well as annual water balance.

Streamflow increased 19% following clearing of the vegetation in preparation for planting. After afforestation streamflow decreased 68 mm/year until after 7 years of forest growth streamflow had decreased to 70% of that in the calibration period. At the same time summer streamflow had decreased to 50% of the pre-harvest period.

Hewitt, A.M.; Robinson, A. 1983a: Moutere gravels land use. A study of comparative water yields. New Zealand Hydrological Society Symposium, Dunedin, 1983. (Unpublished).

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; *P. radiata*	
Land-Use Change: Afforestation	
Stand Type: Plantation 3 to 8 yr	
Keywords: Water yield	

Comment
Presents data from the Kikiwa suite of catchments, Nelson.

Graham Creek	planted in exotics from pasture
Hunters Creek	beech forest control
Kikiwa Creek	pasture control

On an annual basis there was no major change in streamflow yield at Graham Creek in the period when trees were aged 3 to 7 yr. However, over a 4-month summer period Graham streamflow declined from 112% of Hunters to 55% of Hunters while at Kikiwa the summer flow remained in the 80–90% of Hunters range. No data given to back up these statements.

Hewitt, A.M.; Robinson, A. 1983b: Moutere gravels land use. A study of comparative water yields. Unpublished typescript.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; *P. radiata*	
Land-Use Change: Afforestation	
Stand Type: Plantation 3 to 8 yr	
Keywords: Water yield	

Comment
A more extensive version of Hewitt & Robinson (1983a).

Presents data from the Kikiwa suite of catchments, Nelson.

Graham Creek	474 ha	planted in exotics from 1974
Hunters Creek	502 ha	beech forest
Kikiwa Creek	285 ha	pasture

Paper includes some of the forest management history. Most of the forest was planted in 1974 and 1975 and thinning occurred in some compartments in 1980 and 1981.

The data in these tables begin 3 yr after the majority of the Kikiwa was planted. Therefore there is no effective calibration period. Changes in the flow regime should be apparent in the last part of the data set but there is no certain reference point to indicate the comparative situation when planting occurred.

Annual runoff (mm) from Kikiwa suite, Nelson

	Hunters	Graham	Kikawa	Rainfall*
1978	416	510	440	1000
1979	532	600	568	1210
1980	643	646	722	1310
1981	498	548	569	1070
1982	395	390	416	1050
Mean	497	539		

* Rainfall data were extracted off a graph by LKR so there will be some error in these numbers.

Trends in annual runoff after planting are not conclusive.

Summer (December–March) runoff (mm) from Kikiwa suite, Nelson

	Hunters	Graham	Kikawa
1977–1978	71	78	58
1979	76	82	63
1980	144	140	110
1981	13	8	12
1982	56	44	40
1983	67	36	58

Summer-only rainfall data are given. There appears to be a downwards trend in summer flow in the planted catchment.

Hicks, D.M. 1988: Differences in suspended sediment yield from basins established in pasture

and exotic forest. New Zealand Hydrological Society Symposium, Dunedin, 1988. (Unpublished)

Country: New Zealand	Report Location: LKR
Vegetation: Pasture; *P. radiata*	
Stand Type: Plantation	
Keywords: Stormflow; Water quality	

Comment
Whilst a paper about sediment yields, gives the following for Northland catchments:

Topuni	Exotic forest	88 ha	1981–1986	MAP = 1334 mm	Quickflow = 199 mm.
Kokopu	Pasture	308 ha	1981–1986	MAP = 1351 mm	Quickflow = 281 mm.

Hogg, S.E.; Murray, D.L.; Manly, B.J.F. 1978: Methods of estimating throughfall under a forest. New Zealand Journal of Science 21: 129–136.

Country: New Zealand	Duration: 6 months	Report Location: R859
Vegetation: Douglas Fir		
Stand Type: Plantation 50 yr	Stand Density: 440 SPH	
Height: 38 m		Rainfall: MAP ~690 mm
Keywords: Throughfall		

CAB Abstracts AN 780653862

Three gauge networks (stationary 12.7 cm, roving 12.7 cm and trough 130 x 15 cm,) collected throughfall from 21 storms in a 6-ha stand of 50-yr-old Douglas fir, near Dunedin. The three networks gave equally precise estimates of mean TF over the 21 storms, but there were significant differences between storms.

Comment
21 storms
Total PTTN: 283 mm; Throughfall: 134 mm (47%)

Holdsworth, D.K.; Mark, A.F. 1990: Water and nutrient input:output budgets: Effects of plant cover at seven sites in upland snow tussock grasslands of Eastern and Central Otago, New Zealand. Journal of the Royal Society of New Zealand 20: 1–24.

Country: New Zealand	Duration: 2 years	Report Location: LKR
Vegetation: Native Grassland; Pasture		
Keywords: Water quality; Water yield		

Comment
Discusses results from a small lysimeter study on water yields and nutrients. Water yields were greater from snow tussock than blue tussock turf, bare soil, and herbfields; water yield from improved pasture was negligible. Discusses the influence of fog on yields.

Jackson, D.S.; Jackson, E.A.; Gifford, H.H. 1983: Soil water in deep Pinaki sands: some interactions with thinned and fertilised *Pinus radiata*. New Zealand Journal of Forestry Science 13: 183–196.

Country: New Zealand	Duration: 10 yr	Report Location: R750
Vegetation: *P. radiata*		
Land-Use Change: Forest management		
Stand Type: Plantation 4–13 yr	Stand Density: Various	
Keywords: Soil water		

CAB Abstracts AN F922694

In an experiment in Woodhill State Forest, New Zealand, studying the effects of thinning, fertiliser application and the presence of *Lupinus arboreus*, plots treated with both lupin and fertiliser had much greater vol. increment than controls (60–70% more over 13 yr). Depletion of soil water by these stands was also much greater, and could cause critically low soil water potential (-5 bars or less) throughout the profile during late summer and autumn. Critical depletion did not occur in plots without lupin or fertiliser.

During the first 7 yr (up to canopy closure) differences in stocking produced the most significant differences in soil moisture, but only in the top metre. Thinning greatly reduced soil water depletion, particularly in plots with fertiliser, but these effects diminished after 2–3 yr and were insignificant after 5 yr. After canopy closure the effects of fertiliser began to overide those of stocking and produced soil moisture differences down to 3–4 m. Differences in soil water storage between extremes of treatment amounted to approx. 134 mm of rainfall at midwinter.

Comment
Initial stocking 2224 SPH with some plots thinned to 1483, 741 and 371 SPH.

Jackson, R.J. 1972: Water and energy balances of forest and grassland at Taita. Paper presented to New Zealand Hydrological Society Symposium on Water Resources, University of Waikato, November 1972.

Country: New Zealand	Duration:	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Evaporation; Interception; Water balance; Water yield		

Comment
Flow data are presented for the full 15.0 ha Native 1 catchment and a 10.9 ha sub-catchment which excludes the western tributaries and roads, lawns and buildings.

Annual rainfall and runoff (mm) at Taita

	Rainfall	Runoff @ Native 1	Runoff @ Native 2
1956	1585	716	
1957	1499	519	
1958	1130	410	
1959	1378	512	
1960	1166	429	
1961	1262	442	
1962	1610	630	
1963	1115	375	
1964	1141	338	244
1965	1570	604	500
1966	1666	725	600
1967	1275	511	385
1968	1609	692	553
1969	890	235	158
1970	1230	405	306

1971	1052	280	197
1964–1971 Mean	1304	475	368

Differences in yields between the 2 weirs are considered to reflect groundwater movement. Average annual evaporation is in the range 834–1034 mm with interception contributing 400 mm of the total. Interception has been calculated at 30% of rainfall and losses of 6–10 mm/day when rain was persistent were quoted from previous work.

Monthly water balance data (mm) for Taita Native Forest 1 catchment 1964–1971

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall	88	65	97	103	138	135	133	125	123	102	96	101	1305
Interception	26	20	29	31	41	41	40	37	37	31	29	30	392
Runoff	20	12	18	26	33	40	44	44	42	33	31	25	368
Evaporation Forest	106	88	85	67	65	59	57	57	70	80	85	101	920
Evaporation grass	139	101	75	38	18	5	8	20	45	77	104	126	756

Jackson, R.J. 1973: Catchment hydrology and some of its problems. New Zealand Department of Scientific and Industrial Research Information Series 96: 73–80.

Country: New Zealand	Report Location: R1484
Vegetation: Native evergreen forest; Pasture	
Keywords: Evaporation; Stormflow; Water yield	

Comment

Shows differences between storm hydrograph for Puruki and Purutaka in pasture and Puruorakau in native forest with the pasture catchments having significantly greater total and peak flows. At Taita near Wellington, differences in storm hydrographs were not as clear between the second-growth native forest catchment and that with 2/3rds in pasture and the central and stream portions still in scrub. Presents monthly rainfall, evaporation and runoff data which make up the annual totals given here and 5 months of evaporation for grass and manuka calculated from soil water measurements.

Annual rainfall, runoff and evaporation at Taita

	1970	1971	1972
Rainfall (mm)	1230	1052	1110
PE grass (mm)	784	797	781
Native catchment Runoff (mm)	306	197	204
No 5 catchment runoff (mm)	356	215	196

Jackson, R.J. 1983: Evaporation from pasture and radiata pine forest at Ashley, Canterbury. New Zealand Hydrological Society Symposium, Dunedin, 1983. (Unpublished)

Country: New Zealand	Duration: 2 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*		
Stand Type: Plantation		
Keywords: Evaporation; water yield		

Comment
1981: Precipitation 750 mm; Pine catchment runoff 30 mm; Pasture catchment runoff 120 mm.
1982: Precipitation 600 mm; No significant runoff from either catchment.

Pasture catchment: When soil moisture was adequate, evaporation followed Penman PE—2 mm/day September to 4.5 mm/day in December. Declined rapidly when soil moisture deficit reached 80 mm. Maximum SWD = 120 mm.

Pine catchment: Transpiration 2–2.5 mm/day in November/December falling to 0.5 m/day in late summer; Winter rates 0.5 to 1.0 mm/day. Interception contributed 1/3 of the total evaporation.

Jackson, R.J. 1984: Hydrology of pakihi land, West Coast, South Island. New Zealand Hydrological Society Symposium, Hamilton, 1984. (Unpublished)

Country: New Zealand	Duration: 15 months	Report Location: LKR
Vegetation: Scrubland		
Land-Use change: Drainage		
Keywords: Evaporation; Storm flow; Water yield		

Comment
Larry River catchments near Reefton—L2 at 11.6 ha & L3 at 7.2 ha were still in the scrub cover, L1 at 10.0 ha had been drained and planted a year before the study began.

15 months of data between April 1983 and June 1984. Rainfall = 3220 mm; Runoff from L2 and L3 was 2220 mm. Drainage was assumed to be negligible so the balance is almost entirely evaporation at about 800–850 mm per year. 99 events gave 1630 mm of quickflow = 73% of total runoff. Most of this occurred in 5 storms of 1–3 days duration.

After drainage is appears that quickflow totals remain about the same but peak specific discharges increase 2–3 times and the hydrograph has earlier rises and faster falls.

Jackson, R.J. 1985a: The effects on soil water of conversion from beech/podocarp forest to pine plantation. Proceedings, Soil Dynamics and Land Use Seminar, Blenheim, 1985. New Zealand

Society of Soil Science and New Zealand Soil Conservators Association. Pp. 230–242.

Country: New Zealand	Duration: 3 yr	Report Location:
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation 0–3 yr	Stand Density:	Basal Area:
Keywords: Soil water		

Author's abstract

At Big Bush State Forest, south Nelson, the hydrological regime of small catchments is being investigated to assess the impact of conversion from beech/podocarp forest to plantations of *P. radiata*. Soil water measurements were made in undisturbed beech/podocarp forest and in a nearby catchment that had been clearfelled and recently planted with *P. radiata*. Whereas transpiration by the undisturbed forest caused depletion of soil water storage by almost 100 mm in summer, in the first year after clearfelling little soil drying occurred. Except on the first day after wetting by rainfall, rates of evaporation from bare forest soil were low as a result of restricted water movement through the upper organic soil horizons. Low summer evaporation results in a much larger surplus of water draining to streams in summer from clearfelled catchments than from undisturbed forest catchments. After the first year, regrowth of vegetation increased summer soil drying, initially at only a small proportion of sites, but at all sites by the 4th year after clearfelling.

Jackson, R.J. 1985b: Hydrology of radiata pine and pasture catchments, Ashley, Canterbury. New Zealand Hydrological Society Symposium, Christchurch, 1985. (Unpublished)

Country: New Zealand	Duration: 5 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*		
Stand Type: Plantation—mixed ages 36–40, 11–16, 6–11 yr		
Keywords: Stormflow; Throughfall; Water yield		

Comment

Throughfall measured over 4 year was 65% of precipitation.

Annual rainfall and runoff for Ashley catchments

Year	Rainfall (mm)	Runoff (mm)		Quickflow (mm)	
		Pasture	Pines	Pasture	Pines
1981	770	122	32	40	10
1982	610	0	2	0	0
1983	930	157	79	84	39
1984	1110	180	89**	96	53**
1985*	475	8	2	n.a.	n.a.

* Until October 1995

** Includes an estimate for missing data in the largest event.

Jackson, R.J. 1987: Hydrology of an acid wetland before and after draining for afforestation. International Association of Hydrological Sciences Publication 167: 465–474.

Country: New Zealand	Duration: 3 years	Report Location: LKR
Vegetation: Scrub (manuka)		
Land-Use change: Afforestation; Drainage		
Keywords: Storm flow; Water yield		

Comment

Three 'pakihi' catchments at Larry River near Reefton on the South Island West Coast.

Catchment L1:	Drained and planted with *P. radiata* in 1982 before the weir was installed.
Catchment L2:	Control catchment with 40-year-old manuka scrub.
Catchment L3:	There was an 18-month calibration period before the scrub was crushed in October 1985, burned in February 1985, and drained using a tractor-mounted V-blade in April 1985 before planting the newly formed ridges with *P. radiata* in winter of that year.

Annual precipitation and runoff for control catchment Larry River L2

	1983–84	1984–85	1985–86
Precipitation (mm)	2790	2370	2175
Runoff (mm)	1930	1475	1345
Quickflow (mm)	1420	1020	890

Average peak flow (l/s/ha) before and after treatment of catchment L3

	L2 storm size class	Number of storms	L1	L2	L3
Pre-treatment	5–9.99	13	16.3	7.3	8.9
	10–19.99	8	17.5	12.9	14
	>= 20	4	24.1	22.7	23.4
Post-treatment	5–9.99	10	14.3	7.4	21.3
	10–19.99	3	18.3	13.4	22.5
	>= 20	1	32.9	22.3	76.9

Note that L1 had already been treated in the pre-treatment part of the table and the higher average peak flows reflect this. There are obvious increases in average peak flow after treatment at L3 compared to L2, i.e. there are more large flows after treatment. There were more than 3 times as many peak flows > 10 l/s/ha at L23 than at the control L2.

Jackson, R.J. 1992: Forest management effects on stream flow and water quality in New Zealand. In: Hayes, J.W.; Davis, S.F. (Eds) Proceedings of the Fisheries/Forestry Conference, Christchurch, February 1990. New Zealand Freshwater Fisheries Report No. 26: 45–51.

Country: New Zealand	Report Location:LKR
Vegetation: Pasture; *P. radiata*; Scrubland (gorse)	
Keywords: Review; Water yield	

Comment
Briefly reviews work carried out in New Zealand

Jackson, R.J.; Aldridge, R. 1973: Interception of rainfall by kamahi (*Weinmannia racemosa*) at Taita, New Zealand. New Zealand Journal of Science 16: 573–590.

Country: New Zealand	Duration: 2 yr	Report Location: R227
Vegetation: Native evergreen forest		
Keywords: Interception; Stemflow; Throughfall		

Comment
Taita native catchment 1. 50-year-old
Throughfall commenced when 1 mm of rain had fallen; stemflow commenced after 1.5 mm of rain.

On a storm basis and for events > 1.5 mm with both throughfall and stemflow

Throughfall = 0.480 × Precipitation + 0.07 r = 0.9886
Stemflow = 0.318 × Precipitation − 0.89 r = 0.9816
Net rainfall = 0.798 × Precipitation − 0.81 r = 0.9923

For 23 months, Throughfall = 1007 mm = 48% of 2107 mm precipitation, stemflow = 25 mm =23%, net rainfall = 1540 mm = 73% and interception loss = = 567 mm = 27%

Jackson, R.J.; Fahey, B.D. 1993: Forest harvesting and flood hydrology of small catchments. New Zealand Hydrological Society Symposium, Nelson, 1993. (Unpublished).

Country: New Zealand	Duration: 17 yr	Report Location: LKR
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation −4 to 12 yr		
Keywords: Stormflow		

Comment
Harvesting beech/hardwood forest gave increases in both flood peaks and quickflow depths. In the 5 yr after harvesting there was a 3-fold increase in the number of flood peaks > 8 L/s/ha. In winter, when soils were wet in all catchments, differences in flood peaks and quickflow between the undisturbed native forest and the harvested catchments were small, but there were significant differences at the end of a dry summer, the differences depending on the antecedent soil conditions.

Jackson, R.J.; Marden, M.; Payne, J. 1987: Impact of clearfelling radiata pine forests on soil water at Ashley and Mangatu. New Zealand Hydrological Society Symposium, Gisborne, 1987. (Unpublished).

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: *P. radiata*		
Land-Use Change: Harvesting		
Stand Type: Plantation 45 and 25 yr		
Keywords: Soil water		

Comment
Discusses the impact of dry summer pre-harvest conditions on the recharge of soil moisture stores in the winters following harvesting, and how low winter rains after harvesting may not recharge the soil moisture store with the result that the deficit can carry on to the next spring/summer.

Notes that rainfall interception by the forest canopies was about 35% of precipitation.

Jackson, R.J.; Payne, J. 1995: Hydrology of beech and pine forest catchments, Big Bush, Nelson. New Zealand Hydrological Society Symposium, Christchurch, 1995. (Unpublished).

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation −3 to 14 yr		
Keywords: Water yield		

Comment
The water balance for the native beech forest is:

Precipitation 1550 mm; Runoff 530 mm; Interception 450 mm; Transpiration 430 mm; Groundwater loss 100 mm.

Annual water yield increase for the first 4 yr after harvesting was 375 mm/yr. There was a decline between years 5 and 9 with a temporary increase as a result of thinning. For years 9–14 after harvesting the water yield and flood responses were close to that expected from the pretreatment data indicating evaporation is about the same for the two forest types. Over the 15 yr since harvest, the additional runoff due to harvesting is 2500 mm. It would require greatly increased evaporation over the rest of the rotation (165 mm/yr) for the overall yield of the pine plantation to fall below that of the undisturbed beech forest.

Jackson, R.J.; Rowe, L.K. 1996: Flood hydrology of small catchments in *Nothofagus* forests and *Pinus radiata* plantations, South Island, New Zealand. Hydrology and Water Resources Symposium 1996 "Water and the Environment", Wrest Point Hotel Casino Hobart, Tasmania 21-24 May. Pp. 727–728.

Country: New Zealand	Duration:	Report Location: R1483
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation		
Keywords: Stormflow		

Authors' Abstract
Catchment experiments assessing forest harvesting at two sites with similar natural forest and soils, but differing in annual rainfall (1500 and 2400 mm) are compared. Data for storm events smaller that the mean annual flood provide direct evidence of the contributions of soil water storage and interception to the differing losses when vegetation cover changes. Interception is always important, but soil water storage is important in large events only in a few summer months at the drier site.

Jackson, R.J.; Rowe, L.K. 1997a: Soil water deficit effects on water use and growth of *P. radiata* in Canterbury, New Zealand. IUFRO.

Country: New Zealand	Report Location: LKR
Vegetation: *P. radiata*	
Stand Type: Plantation	
Keywords: Evaporation; Soil Water	

Comment
Compares low rainfall, eastern South Island sites at Ashley, Eyrewell and Chaneys Forest sites. Transpiration at Ashley Forest is low in winter (<0.7 mm/day) and reaches 3.0 mm/day in summer of soil water is not limiting. Transpiration is usually limited by soil moisture supply late in the summer, but the limitations can be in force as early as September if winter rainfall fails to recharge the soil water storage.

At Eyrewell, extraction of soil water was in the top 60 cm with smaller contributions from as far as 1.5 m deep. Total water extraction was in the range 80–100 mm.

At Chaneys Forest where tree growth and transpiration are unrestricted by water supply, 250 mm of moisture was extracted between September and December 1966. Most of the water supply uptake was from just above the water table as the upper 1.5 m of sand retains only 75 mm of available water for the trees.

Jackson, R.J.; Rowe, L.K. 1997b: Effects of rainfall variability and land use on streamflow and groundwater recharge in a region with summer water deficits, Canterbury, New Zealand. 5th Scientific Assembly of the International Association of Hydrological Sciences, Rabat, Poster Proceedings. Pp. 53–56.

Country: New Zealand	Duration: 6 yr	Report Location: LKR
Vegetation: Pasture; *P. radiata*		
Stand Type: Plantation—mixed ages 36–41, 11–17, 6–12 yr		
Keywords: Evaporation; Water yield		

Comment
Maximum evaporation values for the pasture catchment were close to Penman PE values. Monthly maximum values for closed canopy pine forests approximated 0.7 × PE (Penman). For much of the time in summer transpiration is controlled by soil water supply and Egrass and Eforest are similar.

Annual rainfall and runoff for Ashley catchments

Year	Rainfall (mm)	Runoff (mm)		Quickflow (mm)	
		Pasture	Pines	Pasture	Pines
1981	770	122	32	40	10
1982	610	0	2	0	0
1983	930	157	79	84	39

1984	1110	180	89	96	53
1985	830	123	40	64	25
1986	1260	499	398	280	250

This table shows that in an environment such as Ashley, variations in water yield associated with variations in rainfall are much greater than the reductions in water yield when grassland is converted to forest. Constraints on land use offer resource managers only a limited opportunity to influence water yield—management of water storage is required to better utilise winter runoff.

Kelliher, F.M.; Kostner, B.M.M.; Hollinger, D.Y.; Byers, J.N.; Hunt, J.E.; McSeveny, T.M.; Meserth, R.; Weir, P.L.; Schulze, E.D. 1992: Evaporation, xylem sap flow, and tree transpiration in a New Zealand broad-leaved forest. Agricultural and Forest Meteorology 62: 53–73.

Country: New Zealand	Duration: 6 days	Report Location: LKR
Vegetation: Native evergreen Forest		
Keywords: Evaporation		

Comment
Site near Maruia in the South Island.

Evaporation by beech forest

Day	Total evaporation (mm)	Forest floor evaporation (mm)	Weather
36961	2.4	0.5	Clear day
13	2	0.4	Partly cloudy day
14	1.9	0.2	Partly cloudy day
15	2	0.3	Clear day
16	1.7	0.2	Partly cloudy after rain
17	2.3	0.3	Clear day

The one rainstorm of 2.4 mm between 2100 13 March to 0100 14 March produced throughfall of 1.2 mm. Throughfall did not begin until 0.8 mm of rain had fallen in the first 24 minutes of the storm.

Kelliher, F.M.; Whitehead, D.; McAneney, K.J.; Judd, M.J. 1990: Partitioning evapo-transpiration into tree and understorey components in two young *Pinus radiata* D.Don stands. Agricultural and Forest Meteorology 50: 211–227.

Country: New Zealand	Duration: 2 days, March 1986	Report Location: R51
Vegetation: *P. radiata*		
Stand Type: Plantation 4 & 7 yr	Stand Density: See below	Basal Area:
Keywords: Evaporation; Transpiration		

CAB Abstracts AN 900643574/Authors' Abstract

The tree and understorey components of latent heat flux density (LE) in two young *P. radiata* stands in Kaingaroa Forest, near Rotorua, New Zealand, were measured on 18 and 19 March 1986, when there was no soil water deficit. Contributing LE from understorey (LEu) and trees (LEt) was estimated using small weighing lysimeters and the Penman-Monteith equation, respectively. In both stands, the daily contribution of LEu to forest LE was considerable. LEu was nearly equal to LEt in the 4-yr-old stand (which had not been pruned or thinned since establishment), but in the nearby 7-yr-old stand, LEu was 30% less than LEt. In the 7-yr-old stand, the presence of woody debris from pruning and thinning operations covering approx. 60% of the understorey was responsible for the comparative reduction in LEu. Equilibrium LEu was estimated in the 7-yr-old stand and overall was 43% less than measured LEu. Vertical wind statistics, determined near ground level in the relatively open 7-yr-old stand, indicated that gusts regularly penetrated from above the forest to the understorey. These results suggest that forest management effects on the available energy and turbulence regimes below the tree canopy can be important determinants of LEu.

Comment

Haupapa, Kaingaroa Forest:
P. radiata, 7 year old, 9 m tall, 450 SPH, pruned to 5 m.
P. radiata, 4 year old, 2.5 m tall, 2900 SPH; tree crown area fraction 0.2, non-evaporative surface 0.1, open understorey 0.7.
Soil water not limiting.
4-yr-old: clear day transpiration from trees = 1.60 mm, understorey = 1.56, total = 3.16
7-yr-old: clear day transpiration from trees = 1.02 mm, understorey = 0.86, total = 1.88

Kelliher, F.M.; Whitehead, D.; Pollock, D.S. 1992: Rainfall interception by trees and slash in a young *Pinus radiata* D.Don stand. Journal of Hydrology 131: 187–204.

Country: New Zealand	Duration: 13 months	Report Location: R228
Vegetation: *P. radiata*		
Stand Type: Plantation 7 yr	Stand Density:450 SPH	
Height: 9 m		
Keywords: Interception; Soil water; Stemflow; Throughfall		

CAB Abstracts AN 930665137

Rainfall interception was measured from November 1986 to December 1987 in a 7-yr-old *P. radiata* stand in New Zealand pruned and thinned in 1985 to 450 stems/ha. Two-thirds of the trees were high-pruned to 4–5 m in July 1986, with slash from pruning and thinning covering about 60% of

the ground. A total of 1154 mm of rain was recorded in 163 days. Canopy and slash throughfall and stemflow for high- and low-pruned trees were measured. The predominance of convective rather than radiative energy determining wet canopy evaporation rates was indicated by the duration times of canopy wetness and evaporation being divided almost equally between day and night. The effect of rainfall interception on the forest water balance was examined using a biophysical water balance model with parameters derived from stand measurements. Annual evaporation of rainfall intercepted by the tree canopy modelled with the Penman equation was only 9% (100 mm) of rainfall. This was attributed largely to an underestimation of wet tree canopy evaporation during 15 days of higher-intensity rain when daily falls exceeded 20 mm. For the remaining 148 rain days, modelled wet tree canopy evaporation was generally close to the measured 19% of rainfall. Modelled annual wet canopy evaporation emanating from slash was 116 mm (10% of rainfall). Modelled annual tree transpiration and understorey evaporation during fine periods were 367 and 328 mm, respectively. Annual soil drainage/water yield was 270 mm. These results suggest a possible increase in annual water yield of the order of 6% of rainfall (69 mm for the modelling period) in the second year after thinning and pruning.

Comment
Haupapa, Kaingaroa Forest. Trees pruned to 5 m; canopy occupied 24 % of ground area. Thinned at age 5 and pruned to 2 m. At age 6 two-thirds were high pruned to 4–5 m.

PTTN 1154 mm; 336 events, 163 days (864 hours = 10% of the study period). Tree interception was 19%. Slash covered 60% of ground and intercepted 11% of rainfall. One-sided LAI 1.7.

Wetness sensors showed the canopy was wet for 26% of the time. There was an equal probability of rainfall for any hour and emphasised importance of nighttime interception and evaporation.

Canopy storage capacity: trees 0.4 mm (ground area basis) and 0.24 mm(leaf area basis); 0.7 and 0.1 mm for slash

Stemflow = 0.05 × PTTN − 0.18	low pruned trees	$r^2 = 0.87$; PTTN > 7 mm
Stemflow = 0.08 × PTTN − 0.16	high pruned trees	$r^2 = 0.86$; PTTN > 7 mm

From their Fig. 4, we can get an approximate estimate (by LKR) for:
Canopy throughfall TFc = 0.74 × PTTN + ??
Slash throughfall TFs = 0.72 × TFc + ??
= 0.53 × PTTN + ??
Intercepts ?? were not determined by LKR

Canopy Interception = 0.19 × PTTN − ?? $r^2 = 0.90$
Slash interception = 0.11 × PTTN − ?? $r^2 = 0.57$
Intercepts ?? were not given.

Slash interception = 37% of total interception

Shows 1 yr of trends of soil water status—fluctuations ranged about 110 mm

Knight, P.J.; Will, G.M. 1977: A field lysimeter to study water movement and nutrient content

in a pumice soil under *Pinus radiata* forest. II Deep seepage and nutrient leaching in the first 12 years of tree growth. New Zealand Journal of Forestry Science 7: 274–296.

Country: New Zealand	Duration: 12 yr	Report Location: R1597
Vegetation: *P. radiata*		
Stand Type: One tree from age 0 in a field lysimeter		Stand Density: Varies
Keywords: Soil water		

Comment
One tree in a draining lysimeter surrounded by plantation. Planted 1962 (2500 SPH ??). Canopy closure by 1967. In 1971 low pruned and thinned to 1340 SPH. In 1973: BA 42 m^2/ha, mean diameter 18.6 cm, 18 m tall.

Why such big losses when there was no vegetation in years 1–3—evaporation from bare soil and substantial surface runoff???

Noted in years 6–12 seepage averaged 164 mm less than the earlier period. If assume IL = 30% of rain, TRANS calculated as 890 mm/year. Drainage generally begins May and continues through to November.

Drainage from lysimeter

	Precipitation	Drainage	Losses
1961	1231		
1962	2150	573	1577
1963	1179	206	973
1964	1606	354	1252
1965	1444		
1966	1628		
1967	1673	118	1555
1968	1440	211	1229
1969	1370	54	1316
1970	1616	214	1402
1971	1891	385	1506
1972	1315	110	1205
1973	1195	77	1118

Levett, M.P. 1978: Aspects of nutrient cycling in some indigenous and exotic forests in Westland, New Zealand. PhD Thesis, Lincoln College, University of Canterbury

Country: New Zealand	Duration: 2 yr	Report Location: Lincoln University
Vegetation: Native evergreen forest; *P. radiata*		
Stand Type: Plantation 10 & 18 yr	Stand Density: Various	
Keywords: Nutrient Cycling; Throughfall.		

Comment
Included here for completeness but there appears to be a fundamental problem with the data, most likely the rainfall used. The results concluded that throughfall under hard beech and 18-yr-old *P. radiata* were similar and that interception by 10-yr-old *P. radiata* and podocarp/hardwood stands was 1% and 4%, respectively.

Mark, A.F.; Rowley, J. 1976: Water yield of low-alpine snow tussock grassland in central Otago. Journal of Hydrology (New Zealand) 15: 59–59.

Country: New Zealand	Duration: 6 years	Report Location: LKR
Vegetation: Native grassland		
Keywords: Water yield		

Comment
15 non-weighing small lysimeters were monitored for 6 years.

12 month water yield from grassland (mm). Precipitation = 1012 mm.

Cover	Lysimeter throughput
Bare soil	637
Normal snow tussock	618
Burned snow tussock	638
Clipped snow tussock	551
Blue tussock sward	489

Martin, R.J. 1990: Measurement of water use and pasture growth on Templeton silt loam. New Zealand Journal of Agricultural Research 33: 343–349.

Country: New Zealand	Duration: 3 years	Report Location: LKR
Vegetation: Pasture		
Keywords: Evaporation; Soil water		

Comment
Measurements in the top 105 cm of irrigated and non-irrigated plots.
Soil water extraction was mainly from the top 45–60 cm of soil at low water deficits. As the soil dried up, progressively more moisture was extracted from lower depths.

Water use by pasture at Templeton

Period	Rainfall (mm)	Irrigation (mm)	Penman PET (mm/day)	Water use - dry (mm/day	Water use -irrigated (mm/day
6/10/78–18/12/78	193	–	3.8	–	–
18/12/78–5/3/79	94	141	4.6	3.7	6.5
5/3/79–1/5/79	146	–	2.2	–	–
6/9/79–10/12/79	185	–	3.3	4.8	4.9
10/12/79–18/2/80	217	111	4.7	6.9	9.2
18/2/80–2/5/80	218	–	2.5	4.3	4.6
16/9/80–10/12/80	103	106	4.1	3.6	5.2
10/12/80–20/2/81	52	106	4.9	2.0	6.0
20/2/81–12/5/81	91	58	2.5	1.7	2.9

McAneney, K.J.; Judd, M. 1983: pasture production and water use measurements in the central Waikato. New Zealand Journal of Agricultural Research 26: 7–13.

Country: New Zealand	Duration: 2 seasons	Report Location: LKR
Vegetation: Pasture		
Keywords: Evaporation; Soil water		

Comment
Irrigated loamy sands on the Waikato River floodplain.

Priestley-Taylor estimates of maximum evaporation agreed with that calculated from soil moisture measurement while soil moisture was non-limiting. E decreased compared to Emax once the soil water deficit reached 60 to 70 mm. Soil water extraction occurred in the top 100 cm of the profile with 50% coming from the top 30 cm.

McColl, R.H.S.; McQueen, D.J.; Gibson, A.R.; Heine, J.C. 1985: Source areas of storm runoff in a pasture catchment. Journal of Hydrology (NZ) 24:1-19.

Country: New Zealand	Duration: 540 days	Report Location: LKR
Vegetation: Pasture		
Keywords: Water yield		

Comment

A 4.27 ha catchment at Judgeford, north of Wellington.

Total rainfall for the period 2580mm from 219 events: 81 events were sampled with total rainfall = 1520mm, quickflow totalled 562 mm or 37% of rainfall..

McColl, R.H.S.; White, E.; Gibson, A.R. 1977: Phosphorus and nitrate runoff in hill pasture and forest catchments, Taita, New Zealand. New Zealand Journal of Marine and Freshwater Research 11: 729–744.

Country: New Zealand	Duration: 2 years	Report Location: LKR
Vegetation: Conifer; Pasture; Scrubland		
Keywords: Water quality; Water yield		

Comment
Collected data from the Taita catchments.

Exotic forest:	3.97ha; planted 1958 and 1959 in western red cedar, Douglas fir and Corsican pine.
Native forest No 2	10.93 ha; secondary regeneration 25-110 years old; 85% manuka scrub with few pines and up to 20% gorse; 15% native forest
No 4	4.69 ha, similar to No 2 but no beech, up to 40% gorse and some pasture.
No 5	3.6 ha; hill country pasture since 1960. 20% gorse in 1971–3.

Samples taken during low flow (see paper for definition), small floods (= period of runoff in which the peak rate did not exceed 1 mm/h in the No 2 catchment), an large floods (= period of runoff in which the peak rate exceeded 1 mm/h in the No 2 catchment). Data for the 23 months between 1 September 1971 and 31 July 1973.

Precipitation for the study period was not given although MAP = 1295 mm.

Flow regimes of Taita catchments, 1971–1973

	Low flows		Small floods		Large floods		Total Runoff (mm)
	Runoff (mm)	% of total runoff	Runoff (mm)	% of total runoff	Runoff (mm)	% of total runoff	
Exotic Forest	53	29	49	27	75	44	178
Native Forest No 2	113	31	92	25	160	44	365
No 4	36	17	63	30	115	53	214
Hill pasture (No 5)	111	31	88	25	160	44	359

Flows from these catchments are low, being of the order of (10+/- 4)% of precipitation guestimated by LKR from the MAP to be about 2500mm over the 23 months.

McGregor, K.R. 1983: Interception loss from the bracken and slash understory of a pine

forest, Purukohukohu Basin, New Zealand. MSc Thesis, University of Auckland.

Country: New Zealand	Duration: March–August	Report Location: LKR
Vegetation: *P. radiata*		
Stand Type: Plantation	Stand Density: 550 SPH	Height: 15 m
Keywords: Interception; Stemflow; Throughfall.		

Comment
Canopy:
Throughfall 75% of PTTN; on a storm basis TF = −0.094 + 0.82 × PTTN
Stemflow 6.4% of precipitation—stemflow based on crown projection area; on a storm basis SF = 0.029 + 0.036 × PTTN
Interception loss 18% of PTTN; on a storm basis IL = 0.017 + 0.147 × PTTN

Understory
Consisted of bracken (40%) and slash (60%)
Throughfall 74% of canopy throughfall; on a storm basis TF = −0.125 + 0.852 × understory PTTN
Bracken stemflow 6.75% of understory precipitation; on a storm basis SF = 0.045 + 0.015 × understory PTTN
Interception loss 18.6% of understory precipitation; on a storm basis IL = 0.073 + 0.132 × PTTN
Modelled the partitioning of rainfall using the Gash (1979) interception model.

McKerchar, A.I. 1980: Hydrological characteristics of land use catchments in the Nelson area. *In*: Land use in relation to water quantity and quality. Nelson Catchment Board, Nelson. Pp. 122–136.

Country: New Zealand	Duration: 1 yr	Report Location: LKR
Vegetation: Douglas fir, Native evergreen forest; Pasture; Pines; *P. radiata*; Scrubland		
Land-Use change: Forest management		
Keywords: Water yield		

Comment
Data from five Nelson catchments are reported.

Long Gully	232-ha control catchment with, in July 1973, about 58% Native evergreen forest, 31% 15-yr-old Corsican pine and 11% open areas & roads.
Rough'ns Creek	300-ha catchment; 50% in *P. radiata* in 1965; 90% by1975. Note that this is not the same sampling position used by Graynoth (1979, 1992).
Graham Creek	474 ha; Reverting pasture converted to exotic forest in 1975
Hunters Gully	483 ha; Untouched beech forest
Kikiwa	285 ha; Rough pasture with bracken and pockets of scrub

12 months of data—March 1978 to February 1979

Water balance for selected Nelson catchments, 1978–79

		March–May	June–August	September–November	December–February	Total
Rough'n	Precipitation Runoff Evaporation	250 50	355 241	278 171	318 35	1201 497 704
Graham	Precipitation Runoff Evaporation	203 26	337 221	307 187	371 78	1218 512 706
Hunters	Precipitation Runoff Evaporation	214 29	334 181	290 146	313 71	1151 427 724
Kikiwa	Precipitation Runoff Evaporation	201 25	316 211	319 150	325 61	1161 447 714

Evaporation = precipitation − runoff

During this year, annual yields from the four catchments in differing vegetation covers were similar. Seasonally yields were more variable.

Hydrograph separation, Nelson Catchments, 1978–1979

	Streamflow (mm)	Quickflow (mm (%))	Delayed flow (mm (%))
Rough'n	499	151 (30)	348 (70)
Graham	512	141 (28)	371 (72)
Hunters	427	119 (28)	308 (72)

Kikiwa	445	110 (25)	355 (75)

Quickflow (determined using the Hewlett & Hibbert (1967) method) was similar between the catchments ranging between 25 and 30% of total streamflow.

McKerchar, A.I.; Waugh, J.R. 1976: Factors affecting the water yield from natural catchments in New Zealand. New Zealand Department of Scientific and Industrial Research Information Series 126: 137–149.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture	
Keywords: Low flow; Water yield	

Comment
Carried out a regionalisation study of annual streamflow using regression analysis on data from 57 catchments throughout New Zealand. The best predictors were mean annual precipitation and average altitude. Catchment area and percentage of forest cover had regression coefficients not significantly different from zero. Shows examples of flow duration curves and concluded that annual rainfall had a dominant influence on the patterns observed. Baseflow recessions are presented for 13 catchments and the importance of geology on these flows was stressed.

McMurtrie, R.E.; Rook, D.A.; Kelliher, F.M. 1990: Modelling the yield of *Pinus radiata* on a site limited by water and nitrogen. Forest Ecology and Management. 30: 1–4.

Country: New Zealand	Duration: 4 yr	Report Location: R60
Vegetation: *P. radiata*		
Stand Type: Plantation 9–12 yr	Stand Density: Various	
Height: 12–15 m	Diameter: 13–19 cm	
Keywords: Evaporation; Model; Soil water		

CAB Abstracts AN 910648965/Authors' Abstract

A process-based model is described and applied to a range of *P. radiata* stands, 9–12 yr old, growing on stabilised sand dunes in a stocking X fertiliser experiment in Woodhill State Forest, New Zealand. The model requires inputs of daily weather data (maximum and minimum air temperatures and rainfall), physical characteristics of the site (longitude, latitude, root-zone depth and relation between root-zone soil matric potential and volumetric water-content) and crop (stocking, crown dimensions and leaf area index) and crop physiological parameters (e.g., maximum stomatal conductance). The model was used to simulate components of forest water-balance and annual net photosynthesis for a defined crop canopy architecture. Simulated daily root-zone water storage in both open and closed canopy stands generally agreed with monthly measurements made over a complete year. Simulated net annual photosynthesis ranged from 23 to 33 t/ha C, and comparison with measured stem-volume annual increments of 12–38 m3/ha over the same time periods resulted in a

strong positive correlation. Ratios of stem-volume increment to net photosynthesis suggested that fertilised and unfertilised stands had a 26 and 14%, respectively, allocation of C to stem growth. Simulations using weather data for a dry year with 941 mm/yr rainfall indicated that annual net photosynthesis and transpiration of fully stocked stands were reduced by 41 and 45%, respectively, compared with those in a wet year with 1553 mm/yr rainfall. Operational applications of the model to forest management in quantifying environmental requirements for stand growth and examining silvicultural alternatives are discussed.

Comment
Discussion on and an explanation of the BIOMASS model.
Data from Woodhill Forest, Auckland—"soil" is 97% sand, 3% silt. Forest stands have a range of stockings and fertiliser treatments.

Shows graphs of soil water content changes throughout 1 year in the top 3.25 m of soil.− 20 to 80 mm in March rising to about 300 mm in July with recharge.

Also predicts the effect of thinning on evaporation. In a year of average (1270 mm) rainfall, dropping the LAI from 6 to 1 reduces water use from about 1250 to 350 mm/yr (data extracted from graph so accuracy??)

Miller, B.J. 2000: Development of water use models for dryland *Pinus radiata* agroforestry systems. PhD Thesis, Lincoln University.

Country: New Zealand	Report Location: Not sighted
Vegetation: *P. radiata*	
Stand Type: Plantation 3+ yr	
Land-Use Change: Afforestation	
Keywords: Model	

Comment
Included for completeness.

Miller, B.J.; Clinton, P.W.; Buchan, G.D.; Robson, A.B. 1998: Transpiration rates and canopy conductance of *P. radiata* growing with different pasture understories in agroforestry systems. Tree Physiology 18: 575–582.

Country: New Zealand	Duration: 4 months	Report Location: R17
Vegetation: *P. radiata*		
Stand Type: Plantation 3 to 5 yr	Stand Density: Various	
Height: 12–15 m	Diameter: 13–19 cm	Rainfall:

Keywords: Transpiration

Comment
Measurements were done when the trees were about 3½ yr old at Eyrewell Forest at 4444 SPH and about 4½ yr old at 400 SPH at Lincoln. Ground vegetation varied and irrigation was applied at some Eyrewell plots. Tree heights varied considerably between plots: from 1.1 m to 6.8 m at the start of the experiments. Transpiration rates varied between treatments ranging from 1 to 5 mm /day.

Miller, R.B. 1963: Plant nutrients in hard beech. III. The cycle of nutrients. New Zealand Journal of Science 6: 388–413.

Country: New Zealand	Duration: 3 years	Report Location: R444
Vegetation: Native Evergreen Forest		
Keywords: Nutrient Cycling; Throughfall.		

Comment
Site was at Silverstream near Wellington, New Zealand.

Throughfall was between 50% and 60% of the rainfall at Taita, 5 km (= 3 miles) away.
Mean annual precipitation = 1350 mm, mean annual throughfall = 760 mm (57% of precipitation)

Throughfall data (converted from inches to mm)

Year	Taita rainfall	Silverstream throughfall
1956	1455	855
1957	1500	880
1958	1100	550
Mean annual	1350	760

Murray, D.L.; Jackson, R.M.; Campbell, D.I.; Fahey, B.D. 1991: Predicting effects of modifying snow tussock grassland. *In:* Allen, R.G.; Howell, T.A.; Pruitt, W.O.; Walter, I.A.; Jensen, M.E. (Eds). Lysimeters for evapotranspiration and environmental measurements. American Society of Civil Engineers. 228–236.

Country: New Zealand	Duration: 16 months	Report Location: LKR
Vegetation: Douglas fir; Native grassland; Pasture		
Keywords: Transpiration; Water balance		

Comment
Glendhu
Reports some of the water balance data in Murray & Campbell (1990); shows the decline in streamflow from the planted GH2 catchment in comparison to GH1 tussock control catchment; and from an analysis based on the Penman-Monteith equation concludes that tussock has a similar rate of transpiration compared to forest which is lower than for pasture, and that interception losses will be lower than for forest. "Therefore changing vegetation from tussock to either forest or pasture should reduce water yield".

O'Loughlin, C.L.; Rowe, L.K.; Pearce, A.J. 1978: Sediment yields from small forested catchments, North Westland-Nelson, New Zealand. Journal of Hydrology (New Zealand) 17: 1–14.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest	
Keywords: Stormflow; Water quality	

Comment
While a paper on sediment yields, mean flow duration curves for 6 Maimai and 4 Big Bush catchments are given. Also notes the number of storms in flow classes above 3 L/sec/ha, about 45 in 821 days at Maimai and 4 in 608 days at Big Bush.

Parfitt, R.L.; Joe, E.N.; Cook, F.J. 1985: Water use and pasture growth on Judgeford silt loam. New Zealand Journal of Agricultural Research 28: 387–392.

Country: New Zealand	Duration: 2 summers	Report Location: LKR
Vegetation: Pasture		
Keywords: Evaporation; Soil water		

Comment
Extraction of soil water by pasture occurred from the top 60 cm in early summer but to a depth of 1.4 m during periods of severe water deficit. Evaporation was weather controlled when the soil water deficit was less than 85 mm; at greater depths, soil water controlled evapotranspiration.

At a SWD of 120 mm, about 50% of the water extracted was in the top 20 cm of the soil.

Parfitt, R.L.; Roberts, A.H.C.; Thomson, N.A.; Cook, F.J. 1985: Water use, irrigation, and pasture production on Stratford silt loam. New Zealand Journal of Agricultural Research 28: 393–401.

Country: New Zealand	Duration: 2 summers	Report Location: LKR
Vegetation: Pasture		
Keywords: Evaporation; Soil water		

Comment
Stratford gritty silt loam near Normanby in southern Taranaki — a deep volcanic ash soil. Extraction of soil water by pasture occurred to a depth of 1.8 m during periods of severe water deficit. Actual water use and Penman ET were similar until soil water deficit was about 65 mm; at greater deficits, soil water controlled evapotranspiration.

At a SWD of 125 mm, about 50% of the water extracted was in the top 25 cm of the soil profile and 75% from the top 50 cm.

Pearce, A.J. 1980: Water yield consequences of vegetation changes. *In*: Land use in relation to water quantity and quality. Nelson Catchment Board, Nelson. Pp. 172–199.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; Scrubland	
Keywords: Stormflow; Water yield	

Comment
Presents a discussion on the water use by tall and short vegetation based on overseas studies and data from Maimai and Moutere.

Catchments M6 and M8 were unlogged, M7 was 100% logged, and M9 75% logged.

19 month water balances (in mm) for selected Maimai catchments

	M6 unlogged	M7 100% logged	M8 unlogged	M9 75% logged
Rainfall	3055	3055	3055	3055
Runoff	1500	2635	1605	2460
Interception	710	0	710	180
Groundwater loss	160	160	160	160
Transpiration	685	0	580	160
Soil evaporation	0	260	0	195

Groundwater loss was assumed to be 100 mm/year
Transpiration by difference and assumed to be 0 where logged
Soil evaporation by difference and assumed to be 0 where unlogged.

Pearce, A.J.; McKerchar, A.I. 1979: Upstream generation of storm runoff. In: Physical Hydrology: the New Zealand Experience. New Zealand Hydrological Society. Wellington. p165–192.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; Scrubland	
Keywords: Stormflow	

Comment

Carried out flow separation by the Hewlett and Hibbert (1967) method on streamflow data collected from 9 locations in the North Island and top half of the South Island. Discusses flow generation each of the areas in relation to rainfall intensity, soil types and the significance of rapid subsurface flow or Horton overland flow mechanisms.

Pearce, A.J.; O'Loughlin, C.L.; Jackson, R.J.; Zhang, X.B. 1987: Reforestation: on-site effects on hydrology and erosion, eastern Raukumara range, New Zealand. International Association of Hydrological Sciences Publication 167: 489–497.

Country: New Zealand	Report Location: R1345
Vegetation: Pasture; *P. radiata*	
Stand Type: Plantation 23 yr	Rainfall: MAP 1350 mm
Keywords: Evaporation; Interception; Transpiration; Water yield	

Comment

Interception 35% of rainfall = ~ 470 mm/yr.
Stand transpiration was determined as the residual of the soil water balance for 2-week periods using TF as rain input and net SM storage changes. Summer transpiration is 2.5–3.5 mm/day when SM is not limiting; c.f. Priestley Taylor 4–4.5 mm.day for pasture with SM not limited.
Transpiration from May to August was <1 mm/day.
Annual transpiration total ~550 mm.
Hence evaporation is 1020 mm for 1350 mm rain which implies streamflow = 330 mm. Pasture estimate for E using the Priestley-Taylor method is 850 mm/yr implying streamflow = 500 mm. Afforestation would therefore reduce streamflow by 170 mm ~ 30%.

Pearce, A.J.; O'Loughlin, C.L.; Rowe, L.K. 1976: Hydrologic regime of small undisturbed beech forest catchments, North Westland. New Zealand Department of Scientific and Industrial Research Information Series 126: 150–158.

Country: New Zealand	Duration: 1 year	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Stormflow; Water quality; Water yield		

Comment

Presents the first year of data from the Maimai experimental catchments near Reefton.

Maimai catchments, Reefton, December 1974–November 1975

	M5	M6	M8	M13	M14	M15
Area (ha)	2.31	1.63	3.84	4.25	4.62	2.64
Runoff (mm)	1578	1532	1213	1775	1948	1355
Mean specific discharge (L/sec/ha)	0.5	0.49	0.39	0.56	0.62	0.43
Losses (mm)	1085	1131	1450	888	715	1308
Quickflow (mm)	808	920	779	992	1012	739
Delayed flow (mm)	764	607	425	769	924	594
Peak specific discharge (L/sec/ha)	40.3	41.7	54.4	63.3	52.8	52.9
Sediment yield (m^3/km^2/year)	135	142	14	21	25	43

Flow separation by the Hewlett and Hibbert (1967) method.

Pearce, A.J.; Rowe, L.K. 1979a: Forest management effects on interception, evaporation and water yield. Journal of Hydrology (New Zealand) 18: 73–87.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Scrubland	
Keywords: Interception; Water yield	

Comment
Reviews data from Maimai, Donald Creek, Moutere, and Taita, and comments on the likely changes to the magnitude of water yield with a change in vegetation cover. Notes that interception loss is a major component of total catchment evaporation, that this loss increases with annual rainfall and canopy wetness, and that the high rates of evaporation of intercepted water during rainfall can be supported by the expectations that surface resistance reduce to zero or near-zero when the forest canopy is wet.

Pearce, A.J.; Rowe, L.K. 1979b: Interception, evaporation and water use by forests. Proceedings, New Zealand Hydrological Society Symposium 1979: 108–110.

Country: New Zealand	Report Location: LKR
Keywords: Interception; Water yield	

Comment
Presents the Penman-Monteith equation for evaporation from vegetation and discusses how aerodynamic and surface resistance of differing vegetation type influences transpiration and interception and the implications for the water balance.

Approximate parameter values for various vegetation surfaces

	Open water	Grass	Field Crop	Forest
Roughness length (m)	0.001	0.01	0.1	1
Aerodynamic resistance (sec/m)	200	115	50	12
Surface resistance (sec/m)	0	40	60	120
Rs/Ra	0	0.3	1.2	10

Pearce, A.J.; Rowe, L.K. 1981: Rainfall interception in a multi-storied, evergreen mixed forest: Estimates using Gash's analytical model. Journal of Hydrology 49: 341–353

Country: New Zealand	Duration: 2 yr	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Interception		

Comment

Tests Gash's model on 2 years of Maimai data with satisfactory results.

Pearce, A.J.; Rowe, L.K.; O'Loughlin, C.L. 1980: Effects of clearfelling and slash-burning on water yield and storm hydrographs in evergreen mixed forests, New Zealand. International Association of Hydrological Sciences Publication No. 130: 119–127.

Country: New Zealand	Duration 19 months	Report Location: LKR
Vegetation: Native evergreen forest		
Land-use change: Conversion from one forest to another		
Keywords: Evaporation; Interception; Water Balance; Water yield		

Comment

Catchments M6 and M8 were unlogged, M7 was 100% logged, and M9 75% logged.

19 month water balances (in mm) for selected Maimai catchments

	M6 unlogged	M7 100% logged	M8 unlogged	M9 75% logged
Rainfall	3055	3055	3055	3055
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Groundwater loss	160	160	160	160
Transpiration	685	0	580	160
Soil evaporation	0	260	0	195

Groundwater loss was assumed to be 100 mm/year
Transpiration by difference and assumed to be 0 where logged
Soil evaporation by difference and assumed to be 0 where unlogged.

Flood peaks increased as a consequence of harvesting with the largest increases in the smallest events.
For events at M6 in flow class 2–4.99 l/s/ha, M7 peaks were 67% higher and M9 peaks 55%
For events at M6 in flow class 5–9.99 l/s/ha, M7 peaks were 50% higher and M9 peaks 41%
For events at M6 in flow class 10–20 l/s/ha, M7 peaks were 30% higher and M9 peaks 32%

Quickflow yields (determined using the Hewlett & Hibbert (1967) method) increased following harvesting. The increases were largest in small events although for events greater that 60mm at M6, M7 quickflow was still 20% greater.

Pearce, A.J.; Rowe, L.K.; O'Loughlin, C.L. 1982: Hydrologic regime of undisturbed mixed evergreen forests, South Nelson, New Zealand. Journal of Hydrology (New Zealand) 21: 98–116.

Country: New Zealand	Duration: 3 yr	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Evaporation; Interception; Water Balance; Water yield		

Comment

Three years of data from the Big Bush (Donald Creek) catchments before harvesting three of them took place.

The average annual water balances for catchments 1–3 (top line) and catchment 4 from 2 years of data (in mm) are:

Precipitation =	Interception +	Quickflow +	Delayed flow +	Transpiration +	Groundwater loss
1480	435	190	340	320	195
1480	435	205	440	360	40

One catchment, DC2, dried up in summer 1978 for 7% of the year. Overall, summer low flows of the order of 0.15 mm/day can be expected most summers.

Pearce, A.J.; Rowe, L.K.; O'Loughlin, C.L. 1984: Hydrology of mid-altitude tussock grasslands, Upper Waipori catchment: II Water balance, flow duration and storm runoff. Journal of Hydrology (New Zealand) 23: 60–72

Country: New Zealand	Report Location: LKR
Vegetation: Native grassland	
Keywords: Evaporation; Interception; Water Balance; Water yield	

Comment

Three years of data from the Glendhu catchments before planting of one took place.

The annual water balance in mm is:

Precipitation =	Interception +	Quickflow +	Delayed flow +	Transpiration
1305	260	250	585	210

Interception was estimated from winter water balance, transpiration as the residual in the annual water balance, and quickflow and delayed flow were found using the Hewlett and Hibbert (1967) separation method. Interception may have been over-estimated and is likely to be closer to 195 mm so transpiration could be more at about 275 mm. Quickflow is about 30% of total runoff.

Pearce, A.J.; Rowe, L.K.; Stewart, J.B. 1980: Nighttime, wet canopy evaporation rates and the water balance of an evergreen mixed forest. Water Resources Research 16: 955–959.

Country: New Zealand	Duration: 3 yr	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Evaporation; Interception; Water Balance; Water yield		

Comment
35 storms which occurred between 1900 and 0700 local time.
Mean rainfall rate = 1.77 mm/hr
$IL = 0.74 + 0.21 \times P$ $r = 0.83$.
Mean evaporation rate for night time storms = 0.37 mm/hr

This compares to 0.28 mm/hr for winter storms and 0.46 mm/hr for summer storms, both night and day time events.

Riddell, J.M. Martin, G.N. 1982: Estimating annual water yields from forest and pasture catchments. New Zealand Hydrological Society Symposium, Auckland, 1982. (Unpublished).

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; Pasture; *P. radiata*	
Keywords: Water yield	

Comment
Used annual water yield data from 38 pasture, 32 native forest and 20 pine forest catchments.

Concluded from mean runoff versus mean precipitation plots that:
Pasture catchments have a greater runoff than forested catchments.
In the rainfall range where native forest and pine plantation catchments overlap, relationships between runoff and rainfall were indistinguishable.

For pasture catchments

$RO = 0.60 \times PTTN - 267$	$P < 1400$ mm	$n = 28$	$r = 0.758$
$RO = 1.4 \times PTTN - 1477$	$P >= 1400$ mm	$n = 20$	$r = 0.938$

For forested catchments

$RO = 0.68 \times PTTN - 605$ P < 1600 mm n = 12 r = 0.797

$RO = 1.24 \times PTTN - 1537$ P >= 1600 mm n = 40 r = 0.985

Rowe, L.K. 1975: Rainfall interception by mountain beech. New Zealand Journal of Forestry Science 5: 45–61.

Country: New Zealand	Duration: 5 years	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Interception; Stemflow; Throughfall		

Comment
A 5-year, summer only, study of interception in a native forest at the Craigieburn Range, Canterbury. Two study plots were used for 2 years and 3 years with the equipment having been relocated to a site with different aspect. Measurements for the first 2 years were made each fortnight and at the second site after each storm.

Interception balance, mountain beech forest

	Throughfall (mm)	Stemflow (mm)	Interception loss (mm)	Rainfall (mm)
1965–1966	176	2	96	274
1966–1967	412	6	292	710
1968–1969	329	8	224	561
1969–1970	387	10	255	652
1970–1971	403	10	228	641
Total	1707	36	1095	2838

Throughfall was 60% of summer gross precipitation, stemflow 1% and interception loss 39%.

On a storm basis (mm)

Throughfall = $-1.9 + 0.69 \times$ Rainfall n=88 F = 1205**

Interception loss = $1.9 + 0.29 \times$ Rainfall n=88 F = 217**

Interception storage capacity ~ 2.7 mm

Rowe, L.K. 1979: Rainfall interception by a beech-hardwood-podocarp forest near Reefton, North Westland New Zealand. Journal of Hydrology (New Zealand) 18: 63–72.

Country: New Zealand	Duration: 3 years	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Interception; Stemflow; Throughfall		

Comment
A 3-year study of interception in a native forest at the Maimai catchments, north Westland.

Interception balance, Maimai

	Throughfall (mm)	Stemflow (mm)	Interception loss (mm)	Rainfall (mm)
1975–1976	1570	30	610	2210
1976–1977	1430	30	480	1940
1977–1978	1540	30	500	2070
Mean	1510	30	530	2070

Throughfall was 73% of gross precipitation. Seasonal differences were apparent with throughfall varying between 77% in winter and 68% in summer.

Storm basis (mm)
Summer: Throughfall = −1.51 + 0.75 × Rainfall
Winter: Throughfall =−1.60 + 0.84 × Rainfall

Stemflow 1.5% of gross precipitation.

Interception loss = 26% of gross precipitation; summer 30% and winter 21%.
Interception storage capacity ~ 2 mm

Rowe, L.K. 1983: Rainfall interception by an evergreen beech forest, Nelson, New Zealand. Journal of Hydrology 66: 143–158.

Country: New Zealand	Duration: 4 years	Report Location: LKR
Vegetation: Native evergreen forest		
Keywords: Interception; Stemflow; Throughfall		

Comment
A 4-year study of interception in a native forest at the Donald Creek catchments, southwest Nelson.

Interception balance, Donald Creek

	Throughfall (mm)	Stemflow* (mm)	Interception loss (mm)	Rainfall (mm)
1977–1978	925	25	390	1345

1978–1979	1080	30	435	1540
1979–1980	1215	35	535	1780
1980–1981	910	25	370	1305
Mean	1035	30	430	1490

* Stemflow estimated at 2% of rainfall

Seasonal differences were apparent with interception loss varying between 22% in winter and 35% in summer.

Monthly basis (mm)

Winter:	Throughfall = −7.5 + 0.78 × Rainfall	r= 0.988	n = 24
Summer:	Throughfall = −5.2 + 0.70 × Rainfall	r= 0.996	n = 22
Winter:	Interception loss = 7.9 + 0.20 × Rainfall	r= 0.840	n = 24
Summer:	Interception loss = 4.9 + 0.28 × Rainfall	r= 0.973	n = 22

Storm basis (mm)

Winter:	Throughfall = −0.83 + 0.78 × Rainfall	r= 0.996	n = 199
Summer:	Throughfall =−0.90 + 0.73 × Rainfall	r= 0.993	n = 210
Winter:	Interception loss = 0.83 + 0.20 × Rainfall	r= 0.946	n = 199
Summer:	Interception loss = 0.93 + 0.25 × Rainfall	r= 0.958	n = 210

Interception storage capacity ~ 2 mm
Mean evaporation rate from the saturated canopy = 0.53 mm/hr in summer and 0.39 mm/hr in winter.

$\%I/R = -5.9 \times [\sin(30 \times X + 1.0)] + 29.1$
where X= number of months since 1 April (X = 0.5 for April, 1.5 for May to 11.5 for March), mean monthly %I/R = 29.1; wave amplitude = −5.9; phase shift from 1 April = 1° = 1 day.

Four models were tested—storm linear regression, monthly linear regression, monthly sine curve and Gash's model—all with satisfactory results.

Rowe, L.K. 1998: Forestry and water resources. Catchment Connections (Landcare Research, Lincoln) 3: 7–8

Country: New Zealand	Report Location: LKR
Vegetation: Pasture; *P. radiata*	
Keywords: Water yield	

Comment
Presents data and discusses in general terms observed changes in streamflows following afforestation in the following regions: Waiwhiu (Northland), Otago, Canterbury, and East Coast North Island. Notes that in regions with annual rainfall about 600 mm, there will be little difference in flows from pasture and pine forested catchments. In fact, there may be no flow from either. Also changes in flows as parts of large catchments are planted may not be detectable.

Rowe, L.K.; Fahey, B.D. 1988: The Maimai hydrological study: Some conclusions ten years after harvesting indigenous forests. New Zealand Hydrological Society Symposium, Dunedin, 1988. (Unpublished).

Country: New Zealand	Duration: 11 yr	Report Location: LKR
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation −1 to +10 yr		Rainfall: MAP 2450 mm
Keywords: Water quality; Water yield		

Comment
Mean annual rainfall: LM 2400 mm; UM 2330 mm.
Mean annual runoff: M6 1320 mm; M15 1270 mm for native forest = 54% of rainfall.

After harvesting, first year increases for the four treated catchments were generally in the range 400–600 mm. Three was a rapid decrease in the extra runoff in the 3 yr after harvesting with prolific regrowth and after 6 yr it was back to pretreatment levels.

Also presents data on water quality aspects.

Rowe, L.K.; Fahey, B.D. 1991: Hydrology and water chemistry changes after harvesting small, indigenous forest catchments, Westland, New Zealand. International Association of Hydrological Sciences Publication No. 203: 259–266.

Country: New Zealand	Duration: 10 yr	Report Location: LKR
Vegetation: Native evergreen forest; *P. radiata*		
Land-Use Change: Conversion from one forest to another		
Stand Type: Plantation −3 to +7 yr		Rainfall: MAP 2450 mm
Keywords: Water quality; Water yield		

CAB Abstracts AN 920663081/Authors' Abstract

After a 2- to 3-yr calibration period, four of six small (1.63 to 4.62 ha) catchments on the west coast of New Zealand's South Island were subjected to various harvesting treatments (clear-felling ± riparian reserve, burning or spraying with desiccant) and then were planted with *P. radiata*. Streamflow yields increased after treatment up to 550 mm/yr, but increases were not in the order expected from a ranking of treatment severity. After about 7 yr of vegetation regrowth, streamflow

seemed to stabilise at a level about 200 mm/yr less than that before treatment. The burnt catchments had the largest initial increases in streamwater electrical conductivity and cation and NO^3 concentrations, but, apart from K, these returned to pre-treatment levels in about 2 yr. Unburnt catchments with riparian reserves were least affected. After treatment, cation yields were highest for the catchment with the largest runoff amounts.

Rowe, L.; Fahey, B.; Jackson, R.; Duncan, M. 1997: Effects of land use on floods and low flows. Ch. 6 in Mosley, M.P.; Pearson, C.P. (Eds.) Floods and Droughts: the New Zealand Experience. New Zealand Hydrological Society, Wellington. Pp. 89–102.

Country: New Zealand	Report Location: R1602
Vegetation: Native evergreen forest; Native grassland; Pasture; *P. radiata*; Scrubland	
Land-Use Change: Afforestation; Conversion from one forest to another	
Keywords: Low flow; Review; Storm flow	

Comment
Reviews many of the New Zealand studies on the effects of land-use change on the hydrology of New Zealand catchments.

Rowe, L.K.; Marden, M.; Rowan, D. 1999: Interception and throughfall in a regenerating stand of kanuka (*Kunzea ericoides* car. *ericoides*), East Coast region, North Island, New Zealand, and implications for soil conservation. Journal of Hydrology (New Zealand) 38: 29–48.

Country: New Zealand	Duration: 3 yr	Report Location: LKR
Vegetation: Scrubland (kanuka)		
Keywords: Interception; Stemflow; Throughfall		

Comment
16–40-year-old kanuka, 13 m tall, 3900 SPH. MAP = 1630 mm.

Annual interception balance (in mm) for the 3 years was
precipitation = throughfall + stemflow + interception loss
1780 1020 20 740
Throughfall was 57% of precipitation, stemflow 1% and interception loss by difference was 42%.

Storm interception loss (in mm) was: IL = 0.36 × PTTN + 2

Rowe, L.K.; Pearce, A.J. 1994: Hydrology and related changes after harvesting native forest catchments and establishing *Pinus radiata* plantations. Part 2. The native forest water balance and changes in streamflow after harvesting. Hydrological-Processes 8: 281–297.

Country: New Zealand	Duration: 12 yr	Report Location: LKR

Vegetation: Native evergreen forest; *P. radiata*	
Land-Use Change: Conversion from one forest to another	
Stand Type: Plantation −3 to 9 yr	Rainfall: MAP 2450 mm
Keywords: Water yield	

CAB Abstracts AN 950611743/Authors' Abstract

Six small, steep, south-west facing catchments (1.63–4.62 ha) have been monitored in Westland, New Zealand since 1974. Two catchments were retained as native mixed evergreen forest and the rest were subjected to various harvesting and land preparation techniques (clear- felling, slash burning, herbicide treatment, riparian protection) before being planted with *P. radiata* between 1977 and 1980. The 11-yr water balance for the native forest catchments was: rain = stream flow + interception loss + transpiration + seepage (2370 mm = 1290 mm + 620 mm + 360 mm + 100 mm). In the year after treatment stream flow generally increased by 200–250 mm, except for one treatment (clear-felling, herbicide application, no riparian reserve) where the increase was 550 mm. The catchments were planted with *P. radiata*, but rapid colonisation by bracken (*Pteridium esculentum*) and Himalayan honeysuckle (*Leycesteria formosa*) led to a rapid decline in stream flow, which returned to pre-treatment levels after an average of about 5 yr. Stream flow yields then continued to decline for another 2–3 yr before stabilising at a level about 250 mm/yr lower than pre-treatment levels. At this time the catchments had a dense bracken/honeysuckle understorey beneath 5-m-tall *P. radiata*.

Comment

Data from the Maimai catchments, near Reefton, West Coast.

M6 and M15 were retained in native beech/podocarp/hardwood forest, the others were clear-felled, and cable logged with (M8, M13) or without riparian reserves, and burned (M8, M14) or not burned before planting.

Rainfall (UM & LM) and runoff for Maimai catchments (mm)

Year	M5	M6	M8	M13	M14	M15	LM	UM
1977	1306	913				806	1888	1840
1978		1075				1069	2138	2087
1979	2441	1419		2040		1297	2625	2462
1980	2624	1775	2029	2216		1538	2827	2711
1981	2058	1363	1687	1779	1615	1323	2482	2356
1982	1745	1070	1414	1522	1335	1119	2253	2144
1983	2322	1688	1991	2082	1863	1633	1996	2735
1984	1919	1324	1597	1636	1417	1261	2468	2303
1985	1374	1130	1229	1324	1325	1160	2193	2107
1986	1418	1250	1250	1396	1334	1167	2247	2133
1987	1818	1554	1654	1731	1674	1446	2668	2461

Year	M5	M6	M8	M13	M14	M15	LM	UM
Mean		1324				1256	2435	2304

Control catchments M6 and M15

Regression relationship determined using the above data were:

$M15 = -630\ (\pm 330) + 0.82\ (\pm 0.14) \times UM$ $r^2 = 0.95$
$M6 = -620\ (\pm 400) + 0.80\ (\pm 0.16) \times LM$ $r^2 = 0.93$
$M15 = 170\ (\pm 230) + 0.82\ (\pm 0.17) \times M6$ $r^2 = 0.95$

Water balance in mm:

	Rainfall =	Runoff +	Interception +	Transpiration +	Seepage
M6	2435	1320	635	380	100
M15	2300	1260	600	340	100

Determined a water balance model with:

$IL\% = 7.1[\sin(0.0172 \times D + 90)] + 26.4$
where IL% = interception loss as a percentage of rainfall for a given month, D is the number of days since 1 January (15 for January, 46 for February,......) and 90 is the value of the phase shift of the calculated sine wave.

$Trans = 1.2[\sin(0.0172 \times D + 90)] + 1.8$
where Trans = transpiration for a rainfree day (<1.0 mm of rain).

Harvesting:

After harvesting, streamflow increases were variable and not that expected from the perceived severity of the operations. In the first year after harvesting the increases were generally in the range 200–260 mm, but was 550 mm at M5, the most severe treatment. Varying annual rainfall in the year following treatment did affect the magnitude of the increases. Because rainfall is high (~2400 mm/yr), reduction of interception alone can easily account for these increases.

Significant regression relationships were developed for determining the expected diminishing yields as the catchments recovered after treatment, but these were variable and inconsistent with the severity of treatment. Annual runoff yields from the catchments were generally back to pretreatment levels after 3–6 yr and did decline to about 20 mm/month lower than pretreatment levels. This was attributed to dense bracken/honeysuckle regrowth as well as tree growth.

Rowe, L.K.; Pearce, A.J.; O'Loughlin, C.L. 1994: Hydrology and related changes after harvesting native forest catchments and establishing *Pinus radiata* plantations. Part 1. Introduction to study. Hydrological-Processes. 8: 263–279

Country: New Zealand	Report Location: LKR

Vegetation: Native evergreen forest; *P. radiata*
Land-Use Change: Conversion from one forest to another

CAB Abstracts AN*: 950601150/Authors' Abstracts*

The hydrology of eight small catchments (1.63–8.26 ha) has been monitored in Westland, New Zealand since 1975. Two of these catchments were left in indigenous beech-podocarp- hardwood forest and the rest were subjected to various harvesting and land preparation treatments before being planted with *P. radiata*. This paper introduces a series of papers on the hydrology of the indigenous forest catchments and the changes that occurred after treatment. The catchments, experimental programme, climate of the area and the rainfall regime experienced between 1975 and 1987 are described.

Comment

Provides background information on the Maimai catchments in North Westland, New Zealand.

Scarf, F. 1970: Hydrological effects of cultural changes at Moutere experimental basin. Journal of Hydrology (New Zealand) 9: 142–162.

Country: New Zealand	Duration: 7 years	Report Location: R1452
Vegetation: Pasture; Scrubland (gorse)		
Land-Use change: Pasture management; Scrub conversion to pasture		
Keywords: Low flow; Storm flow; Water yield		

Comment

Moutere Experimental basin, Nelson.

Catchments 2 (4 ha) and 5 (7.6 ha)	Pasture, mob stocking
Catchment 10 (4.5 ha)	Gorse to cultivation/cropping in 1965

Precipitation and runoff (mm) at Moutere

Year	Catchment 2		Catchment 5		Catchment 10	
	Precipitation	Runoff	Precipitation	Runoff	Precipitation	Runoff
1962*	1099	530	1099	724	1099	323
1963	1038	205	1038	272	1038	88
1964	1191	247	1191	270	1189	56
1965	822	132	824	130	825	62
1966	1105	109	1083	288	1124	153
1967	1016	332	1052	299	1076	215
1968	1129	326	1119	288	1150	177

* 1962 data, May to December only.

All catchments showed marked differences in flows before the treatment took place at C10. This also accorded at the 2 control catchments where C5 had between 0 and 50% more flow. C10 flows were smaller that either control catchments while in gorse and was still lower when cultivated, although mass curves show an increase in runoff after clearing the gorse and cultivation at catchment 10.

After treatment at C10, there was a decrease in the number of days of flow, 19% v 25%, while the reverse occurred at control catchment 5, 76% v 66%. The increase in annual flow was, therefore, a result of increased peak discharges.

Flood peaks increased at C10 after cultivation, but for peaks in excess of 15 mm/h (= 42 l/s/ha) there was little or no increase which was interpreted as "indicating that vegetation cover is relatively ineffective in reducing peak discharges during severe storms".

Schouten, C.J.J.H. 1976: Origin and output of suspended and dissolved material from a catchment in Northland (New Zealand), with particular reference to man-induced changes. Publicaties van het Fysich Geografisch en Bodemkundig Laboratorium va de Universiteit van Amsterdam No 23.

Country: New Zealand	Duration: 9 years	Report Location: LKR
Vegetation: Pasture; Scrubland (manuka)		
Land-Use change: Pasture management; Scrub conversion to pasture		
Keywords: Water yield		

Comment

Puketurua, Northland; 250 ha.

Manuka scrubland was burned in February 1971, disc-cultivated for about a year and planted in pasture between March and May 1972. Grazing began July 1972. By winter 1973, the vegetation cover was: 83% pasture, 4% native bush, 12% gorse/bracken/manuka regeneration.

Precipitation and runoff at Puketurua

Year	Precipitation (mm)	Runoff (mm)
1966	1685	824
1967	1433	565
1968	1849	985
1969	1352	612
1970	1238	507
1971	1570	929
1972	1297	743
1973	1017	480

1974	1219	709

There are two distinct trends for the scrub and bare/grass periods when annual runoff is plotted against annual precipitation, runoff being greater after treatment.

Scotter, D.R.; Clothier, B.E.; Turner, M.A. 1979: The soil water balance in a fragiaqualf and its effect on pasture growth in central New Zealand. Australian Journal of Soil Research 17: 455–465.

Country: New Zealand	Duration: 3 yr	Report Location: R1541
Vegetation: Pasture		
Keywords: Soil water		

Comment
Tokomaru silt loam (=gleyed yellow-grey earth) near Palmerston North. Maximum soil water deficit was 230 mm.

Smith, C.M. 1992: Riparian afforestation effects on water yields and water quality in pasture catchments. Journal of Environmental Quality 21: 237–245.

Country: New Zealand	Duration: 18 yr	Report Location: LKR
Vegetation: Pasture		
Land-Use Change: Afforestation		
Keywords: Water quality; Water yield		

Comment

Moutere catchments 2 (6.95 ha), 3 (2.80 ha) and 5 (2.71 ha).
From 1970 to 1978 the three catchments were grazed. After 1979, C2 continued to be grazed as a control catchment. In August 1978, a 25–35-m strip enclosing the stream channel and lower slopes was fenced off in C3 and C4 and planted at 1400 SPH in *P. radiata*. In late 1983 the trees were thinned to 500 SPH—light grazing was allowed under the trees until mid-1986.

Precipitation and runoff (mm) at Moutere, Nelson

		Catchment C2			Catchment C4		
	Precipitation	Runoff	Quickflow	Delayed flow	Runoff	Quickflow	Delayed flow
1970–1978	1032	271	97	175	214	76	138
1979–1987	1010	266	97	169	161	70	91

Hydrograph separation used the method of Hewlett & Hibbert (1967). The original Table 3 by Smith also gives the range and standard deviations. Streamflow is reduced after pine establishment in the

riparian zone. Quickflow was only slightly lower but was an increased proportion of total flow as delayed flow decreased more. Note that the post-treatment period includes a few years when no effects will be noticeable as the pines will be too small and the use of means could be misleading with respect to the actual change.
The paper does show that in some years between 1982 and 1987: annual runoff was reduced, QF declined by between 52 and 59%, and delayed flow was reduced. Peak flows were reduced in small events, but medium-sized storm peaks were not affected.

Gives the deviations of C4 seasonal data from that predicted from C2 using regression relationships. The seasonal rainfall is given but no flow data for either catchment.

Smith, J.L.H. 1946: Exotic forests and runoff. New Zealand Journal of Forestry 5: 231–232.

Country: New Zealand	Report Location: R1393
Vegetation: *P. radiata*	
Land-Use Change: Afforestation	
Keywords: Water yield	

Comment
Earliest reference in this bibliography on the effects of forests on water yield in New Zealand Maramarua exotic forest with 4040 ha in *P. radiata* of 5650 ha total. Notes experience of farmers that a creek in this forest used to flood regularly washing out bridges while in manuka scrub, the floods are getting progressively smaller.
Also in Tairua, a water supply put in 15 yr previously in bracken and manuka is almost completely dried up. *P. radiata* was planted about the same time.

Smith, P.J.T. 1987: Variation of water yield from catchments under introduced pasture grass and exotic forest, East Otago. Journal of Hydrology (New Zealand) 26: 175–184.

Country: New Zealand	Duration: 8 yr	Report Location: R11
Vegetation: Pasture; *P. radiata*		
Stand Type: Plantation 14–22 yr	Stand Density: Varies	Rainfall: MAP 1000 mm
Keywords: Storm flow; Water yield;		

CAB Abstracts AN S267845/Authors' Abstract
Eight years' data from catchments in Otago, two under introduced grass cover and two under exotic forest cover (*P. radiata* alone and *P. radiata* with *P. nigra*), were analysed for net differences in annual yields, quickflow volumes, delayed flow and recessions. Pasture catchments consistently yielded more water in all facets of the flow regime when compared to exotic forest catchments. Even for storms with high return periods (up to 100 yr) causing simultaneous rainfall over all catchments, the forest catchments yielded less runoff. Recession curves of all catchments showed similar characteristics, but grass catchments consistently yielded more water during recession periods because they always commenced at higher discharges.

Comment
Water year Sept.–Aug. Low intensity (2–3mm/hour) long duration (2–3 days) storms.
Comparative study as no control period data.

Annual yields at North Otago

		Kintore		Vollweillerburn			Jura		Storm	
		Pasture		Pasture			*P radiata & P. nigra*		*P radiata*	
		292 ha		163 ha			192 ha		115 ha	
	PTTN	RO	E	RO	E	PTTN	RO	E	RO	E
1/9/78–79	1061	451	610			1076	196	880	143	933
80	1129	538	591			1106	331	775	205	901
81	885	312	573	273	612	812	221	591	146	666
82	824	237	587	196	628	946	174	772	113	833
83	1165	569	596	574	591	1250	347	902	261	989
84	1033	474	559	410	623	1185	314	871	226	959
85	724	216	508	192	532	771	177	594	96	675
86	1003	374	629	351	652	1178	315	863	131	1047

Quickflow
Pasture: Kintore 601 mm = 28% of RO or 11% of PTTN; Vollweillerburn 640 mm = 32 % RO and 11% of PTTN
Forest: Jura 164 mm = 12% of RO ns 3% of PTTN; Storm 139 mm = 14% of RO and 2% of PTTN.
Flow duration curves higher for pasture that forest as are master recession curves

Swanson, R.H. 1981: Transpiration potential of contorta, radiata pine and Douglas fir for de-watering in mass wasting control. International Association of Hydrological Sciences Publication 132: 558–575.

Country: New Zealand	Duration: 1 yr	Report Location: R1598
Vegetation: Douglas fir; Pines		
Stand Type: Plantation various ages	Stand Density: Various	
Keywords: Transpiration		

Comment
Transpiration measured by sapflux in *P. radiata*, *P. contorta* and Douglas fir at Whakarewarewa and for a number of age and density classes—based on one set of morning and afternoon measurements each month for a year.
Assumed only had transpiration on days with < 1 mm precipitation

Monthly transpiration

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
P. radiata													
5 yr 1600 SPH	63	29	21	55	35	48	124	78	148	194	92	109	996
5 yr 1100 SPH	44	17	13	45	31	36	96	60	104	148	68	82	744
17 yr 1500 SPH	75	36	21	42	31	34	104	64	130	169	78	87	871
26 yr 600 SPH	72	34	18	30	38	38	95	55	101	114	58	65	718
Douglas fir													
15 yr 1600 SPH	42	12	8	18	17	42	140	66	130	202	91	75	843
66 yr 100 SPH	7	3	1	4	3	2	14	10	22	34	20	15	135
P. contorta													
15 yr 2037 SPH	38	12	7	16	9	20	69	36	84	128	63	76	558
31 yr 598 SPH	19	4	4	7	5	9	28	19	39	60	31	39	264
65 yr 321 SPH	26	7	4	11	7	9	27	19	40	61	34	39	258
PTTN	138	81	149	51	161	228	31	122	110	11	190	68	1340
Rainfree days	22	17	19	26	16	14	26	17	23	28	21	25	

Note: 1100 SPH stand was part of 2200 SPH but thinned in March prior to measurements
P. radiata 700–1000 >> *P. contorta* 350–560 >< Douglas fir 140–850.

The sap flux of the thinned trees exceeded that of the unthinned as greater SM available—but total yield in mm was still less.

Comments that sap flux in *P. radiata* decreases with age and stabilises at 13–16 $cm^3/cm^2/hr$. This rate was also found for *P. contorta* and possibly with Douglas fir. Might be a function of growth rate such as the point of inflexion of the sigmoidal growth curve.

Tian, Y.; Singleton, P.L.; Sheath, G.W.; McCall, D.G.; Carlson, W.T. 1998: Modelling animal treading impacts on infiltration rate. Proceddings of the New Zealand Grassland Association 60: 149-152.

Country: New Zealand	Duration: 1 year	Report Location: LKR
Vegetation: Pasture		
Land-Use Change: Pasture management		
Keywords: Soil water		

Comment
Presents data from a study where artificial rainfall via a simulator was applied to a number of plots to

assesses the infiltration recovery rates after stock treading. Measurements in Oct., Dec., and June.

Toebes, C; Scarf, F; Yates, M.E. 1968: Bulletin of the International Association of Scientific Hydrology 13: 95–122.

Country: New Zealand	Duration: 9 years	Report Location: LKR
Vegetation: Pasture		
Land-Use Change: Pasture management		
Keywords: Water yield		

Comment

Makara (Wellington) experimental catchments 1, 2, 5, and 8.

1957–1961 All were in unimproved pasture and hard grazed.

1961 Catchments 1 and 5 were improved by topdressing and oversowing with pasture grasses/clovers. Data available up until 1965.

The data shows that flows from the catchments varied by a factor of 2–3. After subtracting runoff and a Penman PE value from the precipitation input, the balance is attributed to deep percolation.

Precipitation (P in mm) and runoff (R in mm) for Makara pasture catchments

Year	Catchment 1		Catchment 2		Catchment 5		Catchment 8	
	P	R	P	R	P	R	P	R
1957	1410	195	1350	275	1445	290	1500	N/A
1958	1045	125	1035	210	1090	230	1140	105
1969	1120	85	1110	170	1135	200	1195	65
1960	1240	100	1235	180	1290	165	1325	85
1961								
1962	1460	70	1460	210	1610	165	1585	80
1963	1065	90	1105	172	1150	125	1145	105
1964	1050	25	1090	95	1190	65	1150	45
1965	1375	65	1475	205	1510	100	1520	75

Mass curve analysis showed a decrease in flow at catchments 1 and 5 after improvements took place. However the changes in slope were not statistically significant but changes in the intercepts were.

An analysis of the stream hydrographs showed that as a result of pasture improvement there was no significant change in time to peak but there was a significant reduction in peak discharges.

Tomer, M.D.; Knowles, S.F.; Fenton, J.A. Bardsley, W.E.; Oliver, G.R. 1999: Soil water, ground water, and wetland seepage within an effluent irrigated hillslope. Journal of Hydrology (NZ) 38:97-120.

Country: New Zealand	Duration: 9 years	Report Location: LKR
Vegetation: *Pinus radiata*		
Keywords: Soil water		

Comment
The irrigation loading averaging 70 mm/week is equivalent to 3600 mm of effluent per year, more than twice the annual rainfall. Although the soils are highly permeable, irrigation leads to changes of seepage pathways and soil wetness.

Waugh, J.R. 1970a: Baseflow recessions as an index of representativeness in the hydrological regions of Northland, New Zealand. International Association of Hydrological Sciences Publ. 96: 602–613.

Country: New Zealand	Report Location: LKR
Vegetation: Mixed	
Keywords: Low flow	

Comment
Shows how differing geologies in a region can have a marked bearing on baseflow recessions.

Waugh, J.R. 1970b: The relation between summer low flows and geology in Northland, New Zealand. Water and Soil Division, New Zealand Ministry of Works, Misc. Publ No. 6. Pp21.

Country: New Zealand	Report Location: LKR
Vegetation: Mixed	
Keywords: Low flow	

Comment
Shows how differing geologies in a region can have a marked bearing on baseflow recessions. More information is given that in Waugh (1970a).

Waugh, J.R. 1980: Hydrological effects of the establishment of forests. In: Land use in relation to water quantity and quality. Nelson Catchment Board. Pp. 218–249.

Country: New Zealand	Report Location: R1480
Vegetation: Native evergreen forest; Pasture; *P. radiata*	
Land-Use Change: Afforestation	
Stand Type: Plantation Various—young	
Keywords: Review; Water yield	

Comment
Reviews preliminary findings of a number of studies presented in this bibliography. Also includes scrubland to pasture conversions and the effects of different pasture grazing options.

Moutere: Gorse to *P. radiata* Catchments 8 and 13 vs 5 as control. Moutere 14 *P. radiata* planted into pasture. These are updated by Duncan (1995a,b).

Waiwhiu in Northland: 50% of a native evergreen forest/pasture/scrub catchment was converted to *P. radiata* forest . 5 yr under forest/pasture; 18 months scrub clearing and burning; 3 yr of pines and rank grass.
Destocking lead to an decrease in runoff and this continued through the early years of pine growth—attributed to increased interception by rank grass.

Purukohukohu/Puruki: A similar story to that for the Waiwhiu—rank grass in the young pines was the probable cause of the initial flow decreases.

Wells, L.P.; Blake, G.J. 1972: Interception characteristics of some central North Island vegetation and their geographical significance. Proceedings, Seventh Geography Conference, Hamilton. Pp. 217—224.

Country: New Zealand	Report Location: LKR
Vegetation: *P. radiata*; Scrubland (native)	
Stand Type: Plantation 25 yr	
Keywords: Interception	

Comment
Provides graphs of interception loss in the first 15 minutes of a storm (a measure of interception capacity) against rainfall intensity and percentage interception loss vs accumulating storm precipitation for a number of storms for both the 25-yr-old pines at Whakarewarewa (near Rotorua) and native scrub at Otutira.

Whitehead, D. 1987: WATMOD - a means of predicting water use by forests. What's New in

Forest Research No. 154. 4 pp.

Country: New Zealand	Report Location: R1599
Vegetation: *P. radiata*	
Keywords: Model	

CAB Abstracts AN 900644299

WATMOD is a computer model being developed by the Forest Research Institute of New Zealand to predict the effects of a wide variety of management proposals on water availability from forest catchments. The model can already be used to simulate long-term water use and drainage from *P. radiata* forests for many different management prescriptions. Because WATMOD has been based on the processes which affect the overall water balance within a forest, its use is not restricted to a particular site.

Whitehead, D.; Kelliher, F.M. 1991a: Modeling the water balance of a small *Pinus radiata* catchment. Tree Physiology 9: 17–33.

Country: New Zealand	Duration: 1 yr	Report Location: R832
Vegetation: *P. radiata*		
Stand Type: Plantation 13 yr	Stand Density: 575 SPH	Basal Area: 30 m^2/ha
Height: 20 m		Rainfall: 1403 mm
Keywords: Model; Water balance; Water yield		

CAB Abstracts AN 920656647/Authors' Abstract

An hourly biophysical model was used to calculate water balance over a period of 1 yr for an 8.7-ha 13-yr-old *P. radiata* forest in central North Island, New Zealand. Components of the model were transpiration from the dry tree canopy, evaporation from the partially wet tree canopy and stems, evaporation from the understorey and soil, and drainage from a single-layer root zone. Model inputs were hourly weather data (net radiation, air and wet bulb temperatures, windspeed, and rainfall), tree stand characteristics (average height, tree number, leaf area index), physical characteristics of the site (root zone depth, relation between root zone matric potential and volumetric water content, relation between rate of drainage from the root zone and volumetric water content, and area of open-stream channels). A submodel of the response of stomatal conductance to air saturation deficit and root zone matric potential was also required. Tree transpiration (704 mm/yr, or 50% of annual rainfall) was a dominant component of the catchment water balance. Estimated evaporation from wet tree canopy was 203 mm/yr (15%). Evaporation from the understorey was much less, amounting to 94 mm/yr (7%) and an increase in water storage for the 3.5 m root zone depth was estimated to be 53 mm/yr (4%). Estimated daily rates of drainage generally agreed well with measurements of streamflow, although estimated annual drainage (349 mm/yr, 24%) exceeded measured streamflow (234 mm/yr). Significance of the results is discussed in relation to closure of the hydrologic balance.

Comment

Puruki-Rua 8.7 ha; LAI all surfaces 15.5.

PTTN 1403 mm on 155 days;
Model requires hourly climate data, tree stand characteristics, and soil physical data
Streamflow was measured and used to check the other modelled outputs—interception, transpiration, drainage.

Water balance of 13-yr *P. radiata* at Puruki

Month	PTTN	Interception	Tree transpiration	Understorey evaporation	Soil Drainage	Streamflow
8	173	24	32	4	40	56
9	134	17	49	6	75	66
10	133	28	58	9	42	22
11	59	13	81	12	18	12
12	40	11	103	14	5	2
1	179	24	104	15	5	4
2	73	15	82	12	3	1
3	154	16	67	9	6	5
4	174	15	47	5	18	13
5	129	15	30	3	32	15
6	111	18	22	2	56	25
7	44	7	29	3	50	14
Total	1403	203	704	94	350	235
% rain	100	15	50	7	24	

Losses = 1000 mm, drainage 350 mm cf. streamflow of 235 mm; rain = 1403

Whitehead, D.; Kelliher, F.M. 1991b: A canopy water balance model for a *Pinus radiata* stand before and after thinning. Agricultural and Forest Meteorology 55: 109–126.

Country: New Zealand	Duration: 3 yr	Report Location: R236
Vegetation: *P. radiata*		
Land-Use Change: Forest management		
Stand Type: Plantation 11–13 yr	Stand Density: 754 SPH thinned to 334 SPH	
Height: 17+ m		
Keywords: Interception; Model; Transpiration; Water balance		

CAB Abstracts AN 920661462/Authors' Abstract

A model of water balance for a coniferous forest canopy is described which combines the

Penman–Monteith equation to estimate transpiration from the dry canopy (Et) and the Rutter model of interception to estimate evaporation from the canopy and stems wetted by rainfall (Ei). Evaporation from the understorey and forest floor (Eu) estimated from the available energy determined from radiation attenuation by the tree canopy, is also included. The model was applied to an 11-yr-old *P. radiata* stand at Longmile, Rotorua, New Zealand, before and after thinning in 1984. Parameters in the model were determined for the unthinned stand, and changes in the parameters following thinning were estimated from changes in tree number per unit area and leaf area index (LAI). The model was validated using (i) independent measurements of Et from trees growing in weighing lysimeters within the stand, (ii) estimates of evaporation from the canopy, not including the stems (Eic) from measurements of rainfall, throughfall and stemflow, and (iii) measurements of Eu. The model also shows good agreement with measurements of the duration of tree canopy wetness and Et from a drying canopy after rainfall. The model was used to estimate the annual components of canopy water balance for the unthinned and thinned stands during a year with high, well distributed rainfall (1623 mm), when there was no summer drought period. For the unthinned stand, modelled annual Et, Ei and Eu were 636, 268 and 93 mm, respectively, with the net amount of water added to the soil storage (N) being 626 mm. Thinning resulted in a significant reduction (36%) in modelled annual Et, slightly less than the decrease in LAI (42%). The decrease in modelled annual Ei (27%) was much smaller than the decrease in LAI. These results are discussed in relation to the significance of canopy structure in determining evaporative losses from forest canopies and the net addition of water to storage in the soil. During the year following thinning, the model indicated an increase in N of 201 mm (13% of gross rainfall). Implications for managing the water yield from forest catchments are discussed.

Comment

This paper is an update of Whitehead *et al.* (1989) below but a different rainfall period was used for the model output.

Combines Penman–Monteith with Rutter and Gash model components.

Models differences but no apparent validation by field measurement.

Whakarewarewa (Longmile), Rotorua. Planted 1973;

In 1983 754 SPH; 17-m tall, LAI (all surfaces) 15.5; no understorey; closed canopy

Sept 1984, thinned to 334 SPH, 21 m tall; LAI 9, crown cover 46% of ground. 60% ground covered by debris. Well watered.

Modelled canopy water balance

	Unthinned	Thinned
Precipitation (mm)	1623	1623
Tree transpiration (mm (%))	636 (39)	410 (25)
Tree interception (mm (%))	268 (17)	195 (12)
Understorey interception (mm (%))	93 (6)	191 (12)
Balance to Soil Moisture (mm (%))	626 (38)	827 (51)
Losses (mm (%))	997 (62)	796 (49)

Whitehead, D.; Kelliher, F.M.; Hobbs, J.F.F.; Brownlie, R.K.; Godfrey, M.J.S. 1989: A model of the canopy water for a *Pinus radiata* stand before and after thinning. Proceedings, Fourth Australasian Conference on Heat and Mass Transfer, Christchurch, May 1989. Pp. 467–475.

Country: New Zealand	Duration: 3 yr	Report Location: R1190
Vegetation: *P. radiata*		
Land-Use Change: Forest management		
Stand Type: Plantation 11–13 yr	Stand Density: 754 SPH thinned to 334 SPH	
Height: 17+ m		
Keywords: Interception; Model; Transpiration; Water balance		

Comment
Longmile stand at Whakarewarewa, Rotorua.
Storm stemflow: $SF = 0.11 \times PTTN - 0.22$
Storm throughfall (guesstimated from eyeballed . fit through graphed data by LKR)
$TF = 0.76 \times PTTN - 1$
Interception storage capacity estimated to be 0.6 mm.

Selected transpiration values for 1 dry day in given months:

Pre-thinning:	December 3.4 mm	April 2.5 mm	July 1.4 mm	September 2.1 mm
Post-thinning:	January 2.4 mm	April 2.0 mm	July 1.2 mm	October 1.6 mm

The model is shown to work well for both pre- and post-thinning wet and dry canopy evaporation when adjusted for the decrease in leaf area.

Simulated water balance 1985 with annual rainfall of 1347 mm

	Unthinned		Thinned	
	mm	%	mm	%
Tree canopy transpiration	763	57	461	34
Tree canopy evaporation	240	18	187	14
Understorey evaporation	62	4	161	12
Net addition to soil moisture	283	21	539	40

Whitehead, D.; Kelliher, F.M.; Lane, P.M.; Pollock, D.S. 1994: Seasonal partitioning of evaporation between trees and understorey in a widely spaced *Pinus radiata* stand. Journal of Applied Ecology 31: 528–542.

Country: New Zealand	Duration: 1 yr	Report Location: R100
Vegetation: *P. radiata*		
Stand Type: Plantation 7 yr	Stand Density: 450 SPH	
Height: 7.5 m		Rainfall: 1154 mm
Keywords: Transpiration		

CAB Abstracts AN 940608405

Tree transpiration, Et, and understorey evaporation, Eu, were measured hourly on 2–3 fine days during 12 periods throughout a year in a *P. radiata* plantation in Kaingaroa Forest, New Zealand. There were 450 stems/ha and 60% of herbaceous understorey vegetation and forest floor was covered by dead stems, branches and foliage from earlier thinning and pruning operations. Annual rainfall was 1154 mm and trees and understorey vegetation were supplied adequately with water throughout the year. Data are presented and discussed on relations between stomatal conductance, air saturation deficit above the forest canopy, incident quantum flux density, foliage development, night frost, tree canopy leaf area index, canopy conductance, and average daily transmittance of shortwave radiation through the tree canopy. The combination of weather variables, changes in stomatal conductance, increasing leaf area index and the relation between Eu and available energy led to the fraction Et/(Et + Eu) remaining roughly constant throughout the year with an average of 0.52.

Comment

Same stand as Kelliher *et al.* (1992) at Haupapa.
Transpiration ranged between 0.5 mm/day winter and 1.3 mm/day late summer
Understorey evaporation ranged from 0.3 mm to 1.6 mm in early summer

Wilkie, D.R.; Dixie, R.C.; Yates, M.E. 1965. Effects of some land-management practices on the hydrology of small catchments. 11th New Zealand Science Congress, Conservation sub-section, Auckland 1965. P25–37.

Country: New Zealand	Report Location: LKR
Vegetation: Pasture	
Land-Use Change: Pasture management	
Keywords: Water yield	

Comment

Briefly introduces the Moutere Soil Conservation Station and provides some initial results from the Makara Soil Conservation Station.

There as a reduction in flow with treatment as predicted from a control catchment: improved pasture/lax grazed 22.5%; improved pasture/hard grazed 9.8%, unimproved pasture/hard grazed 5.2%; unimproved pasture/lax grazed 1.9%. In storms of less than 25 mm, the effect was more significant with reductions in runoff of: improved pasture/lax grazed 92%; improved pasture/hard grazed 71%, unimproved pasture/hard grazed 47%; unimproved pasture/lax grazed 43%

In storms greater that 25 mm, the picture was not as clear with some treatments having an increase in flow, and one a decrease.

Will, G.M. 1955: Removal of mineral nutrients from tree crowns by rain. Nature, London 1955: 1880.

Country: New Zealand	Duration: 6.25 months	Report Location: R1600
Vegetation: *P. radiata*		
Stand Type: Plantation 30 yr		
Keywords: Throughfall		

Comment
PTTN 687mm, TF 420mm, TF% 61%. November 1954 to June 1955

Will, G.M. 1959a: Nutrient return in litter and rainfall under some exotic conifer stands in New Zealand. New Zealand Journal of Agricultural Research 2: 719–734.

Country: New Zealand	Duration: 2 yr	Report Location: R434
Vegetation: Conifers; Douglas fir; Pines; *P. radiata*		
Stand Type: Plantation 28 & 29 yr	Stand Density: 300 SPH	Height: 36.5 m
Keywords: Nutrient cycling; Throughfall		

Comment
Kaingaroa Forest: Two rain collectors (5.5 in glass funnels) at each site.
P. radiata, 65–70% crown cover
Douglas fir, 33 yr old, 27 m tall, 1240 SPH, 100% crown cover.

Throughfall at Kaingaroa

	Rainfall (mm)	Throughfall (mm)	Throughfall (%)
P. radiata year 1	1854	1346	73
P. radiata year 2	1168	800	68
Douglas fir year 1	1448	800	55
Douglas fir year 2	1930	927	48

Will, G.M. 1959b: Soil-moisture and soil-temperature studies under radiata pine, Whakarewarewa Forest, 1954–1955. New Zealand Journal of Agricultural Research 2: 184–193.

Country: New Zealand	Duration: 1 yr	Report Location: LKR
Vegetation: *P. radiata*		

Stand Type: Plantation 7 yr regeneration & 39 yr
Keywords: Throughfall

Comment
Whakarewarewa, Rotorua.

7-yr-old regenerating stand after clearfelling, 3700 SPH; 10.7 m tall.
39-yr-old stand with no management but mortality reduced stocking to 250 SPH; 35 m tall.

Precipitation for 1 yr was 1510 mm; 7yr throughfall 905 mm, 39 yr throughfall 980 mm.

Will, G.M. 1962: Soil moisture and temperature studies under radiata pine, Kaingaroa Forest, 1956–1958. New Zealand Journal of Agricultural Research 5: 111–120.

Country: New Zealand	Duration: 2 yr	Report Location: LKR
Vegetation: *P. radiata*		
Stand Type: Plantation 28 to 30 yr	Density 300 SPH	
Keywords: Throughfall		

Comment
Kaingaroa Forest
This appears to be the same stand but with slightly different sampling periods as for the Kaingaroa *P. radiata* stand in Will (1959a).

Throughfall under *P. radiata* at Kaingaroa

	Precipitation (mm)	Throughfall (mm)
1956	1855	1525
1957	1105	885

Williams, P.W. 1976: Impact of urbanization on the hydrology of Wairau Creek, North Shore, Auckland. Journal of Hydrology (New Zealand) 15: 81–99.

Country: New Zealand	Report Location: LKR
Vegetation: Native evergreen forest; pasture	
Land-Use Change: Urbanization	

Keywords: Storm flow

Comment
11.4 km^2 Wairau Creek catchment. 1940: over 50% in grassland, 6% roads and residential, balance forest/scrub/swamp.1959 almost 3/4 in bush/scrub/grassland; 1969 < 50% in bush/scrub/grassland; 1974 1/3 bush/scrub/grassland.

Flood peaks increased in size and the increase in numbers was directly related to the built-up area. Time to peak and storm duration both decreased with urbanization.

Woodward, S.J.R.; Barker, D.J.; Zyskowski, R.F. 2001: A practical model for predicting soil water deficit in New Zealand. New Zealand Journal of Agricultural Research 44:91-109.

Country: New Zealand	Report Location: R517
Vegetation: pasture	
Keywords: Soil water	

Comment
Presents measured field data derived for 12 New Zealand soils from 10 different papers on available soil water holding capacity. Also tabulates laboratory measurements from many sources for soils representing main flatland soil orders in New Zealand

Measured available water holding capacities (0-76 cm depth, awhc in mm) for some New Zealand soils (see original for sources of data)

Judgeford silt loam	92	Waikiwi silt loam	188
Otokia silt loam	96	Tokomaru silt loam	91
Tokomaru silt loam	96	Ohakea silt loam	92
Lismore stoney silt loam	61	Stratford silt loam	112
Horotiu sandy loam	101	Horotiu sandy loam	101
Te Kowhai clay loam	92	Te Kowhai silt loam	176

Field measurements of available water holding capacities (mm) (0-76 cm depth) for some New Zealand soils (see original for sources of data)

Judgeford silt loam	92	Waikiwi silt loam	128
Otokia silt loam	96	Tokomaru silt loam	91
Tokomaru silt loam	96	Ohakea silt loam	92

Lismore stoney silt loam	61	Stratford silt loam	112
Horotiu sandy loam	101	Horotiu sandy loam	101
Te Kowhai clay loam	92	Te Kowhai silt loam	176

Laboratory measurements of available water holding capacities (mm) (0-76 cm depth) for some New Zealand soils (see original for sources of data)

Judgeford silt loam	114	Waikiwi silt loam	128
Otokia silt loam	96	Tirau silt loam	131
Tokomaru silt loam	96	Naike clay	70
Tokomaru silt loam	91	Paraha silt loam	92
Tokomaru silt loam	114	Mokutua peaty silt loam	153
Te Kowhai clay loam	176	Judgeford silt loam	92
Te Kowhai clay loam	92	Hamilton clay loam	88
Mangapiri heavy silt loam	93	Stratford silt loam	112
Horotiu sandy loam	101	Himitangi sand	36
Taita clay loam	72	Ohaupo silt loam	118

Have revised the model of Scotter et al. (1979) to predict soil water status for pastures. Need daily rainfall and PET estimates. Actual evaporation is the lesser of PET and readily available water content.

Yates, M.E. 1964. Makara Experimental Station—preliminary results. Soil and Water 1: 19–21.

Country: New Zealand	Report Location: R517
Vegetation: Pasture	
Land-Use Change: Pasture management	
Keywords: Water yield	

Comment
Makara Soil Conservation Station. Same data as Wilkie *et al.* (1965).

There as a reduction in flow with treatment as predicted from a control catchment: improved pasture/lax grazed 22.5%; improved pasture/hard grazed 9.8%, unimproved pasture/hard grazed 5.2%; unimproved pasture/lax grazed 1.9%. In storms of less than 25 mm, the effect was more significant with reductions in runoff of: improved pasture/lax grazed 92%; improved pasture/hard grazed 71%, unimproved pasture/hard grazed 47%; unimproved pasture/lax grazed 43%

In storms greater that 25 mm, the picture was not as clear with some treatments having an increase in flow, and one a decrease.

Yates, M.E. 1971. Effects of cultural change at Makara Experimental Station: Hydrological and agricultural production effects of two levels of grazing on unimproved and improved small catchments. Journal of Hydrology (New Zealand)10: 59–84.

Country: New Zealand	Report Location: LKR
Vegetation: Pasture	
Land-Use Change: Pasture management	
Keywords: Water yield	

Comment

Makara Soil Conservation Station. 8 catchments with 4 years of pretreatment data then 8 years when pasture and stock management changes were made. Catchments 2 & 8 are considered to be the control catchments.

Makara catchment treatments and annual water yields (mm)

Catchments	Grazing level	Pasture status	Mean annual runoff (calibration)	Mean annual runoff (evaluation)
2 & 8	Hard	Unimproved	167	149
1 & 5	Hard	Improved	178	105
3 & 4	Lax	Unimproved	191	147
6 & 7	Lax	Improved	184	99

Greatest changes of similar magnitudes occurred with pasture improvement and a lesser change occurred with lower stocking rates. There were fewer runoff events and these were smaller as a result of land management.

There is a reduction in flow with treatment as predicted from a control catchment: improved pasture/lax grazed 22.5%; improved pasture/hard grazed 9.8%, unimproved pasture/hard grazed 5.2%; unimproved pasture/lax grazed 1.9%. In storms of less than 25 mm, the effect was more significant with reductions in runoff of: improved pasture/lax grazed 92%; improved pasture/hard grazed 71%, unimproved pasture/hard grazed 47%; unimproved pasture/lax grazed 43%

In storms greater that 25 mm, the picture was not as clear with some treatments having an increase in flow, and one a decrease.

Yunusa, I.A.M.; Mead, D.J.; Pollock, K.M.; Lucas, R.J. 1995: Process studies in a *Pinus radiata*-pasture agroforestry system in a subhumid temperate environment. I. Water use and light interception in the third year. Agroforestry Systems 32: 163–183.

Country: New Zealand	Duration: 15 months	Report Location: R111

Vegetation: *P. radiata*	
Stand Type: Plantation 2 yr	Stand Density: 1000 SPH
Keywords: Interception	

CAB Abstracts AN 969602621

Soil moisture storage, evapotranspiration (ET) and light interception were determined in an agroforestry trial near Lincoln, New Zealand, consisting of *P. radiata* grown over (1) control (bare ground), (2) ryegrass/clovers *(Lolium perenne/Trifolium* spp.), (3) lucerne (*Medicago sativa*), and (4) ryegrass only, during the third growing season between 1992 and 1993. In the period when rainfall was frequent and exceeded the evaporative demand (Epot), ET and depletion of soil moisture were not affected by the ground cover treatments. During summer when rainfall was less frequent, but with moisture readily available in the soil profile, ET was associated with the plant canopy, and was significantly higher for the pasture ground covers than for the control. The more rapid growth by lucerne caused higher ET in this ground cover than in the ryegrass/clover ground cover in which the pasture was slow growing. At the end of the study period, total ET was in the following order: lucerne (757 mm) > ryegrass/clover (729 mm) > control (618 mm). ET was dominated by pasture transpiration (Ep) during most of the growing season, but by tree transpiration (Et) in winter when large parts of the pasture canopy was shaded. Ep was always at least 16% higher for lucerne than for ryegrass/clover as a result of a greater radiation intercepted by the former. The fraction of incoming radiation intercepted by the tree crowns was in the following order: control > ryegrass > ryegrass/clover > lucerne. At the end of the 1-yr period, the fraction of intercepted radiation was 140% greater for control than for the lucerne ground cover. The control produced the largest tree crowns - these were almost twice the size of the tree crowns in the lucerne ground cover, which had the smallest trees. Accordingly, the trees in the control intercepted more radiation and rainfall, with the former being lost to evaporation, than the trees in the pasture. The fractions of radiation intercepted and ET accounted for by the trees and pastures were associated with the proportion of the plot area they occupied.

Comment

Agro-forestry trial —pasture with *P. radiata* at 1000 SPH.

Precipitation (14 months) = 915 mm

Interception by trees 8 to 13.7 % but relative to what—tree area or plot area?

Section 4: Supplementary overseas studies on gorse, bracken, and large catchments

(a) Gorse (*Ulex europaeus*)

Calvo de Anta, R.; Paz, A.; Diaz-Fierros, F. 1979: Nuevos datos sobre la influencia de la vegetacion en la formacion del suelo en Galicia. I. Interceptacion de la precipitacion. Anal. Edafol. Agrobiol. 38: 1151–1163,

Country: Spain	Report Location: Quoted in Soto and Diaz-Fierros (1997)
Vegetation: Scrubland (Gorse)	
Keywords: Throughfall	

Comment
9-year-old gorse 0.9 m tall.
Throughfall was 44.8 % of rainfall. Amount??. Period ??.

Soto, B.; Diaz-Fierros, F. 1997: Soil water balance as affected by throughfall in gorse (*Ulex europaeus* L.) shrubland after burning. Journal of Hydrology 195: 218–231. Location: 118

Country: Spain	Duration:	Report Location: R118
Vegetation: Scrubland (Gorse)		
Keywords: Throughfall		

CAB Abstracts AN: 981909738

The role of fire in the hydrological behaviour of gorse shrub in NW Spain was studied from the point of view of its effects on vegetation cover and throughfall. In the first year after fire, throughfall represented _88% of gross rainfall, whereas in unburnt areas it was 58%. Four years after the fire, the throughfall coefficients were similar in burnt and unburnt plots (_60%). The throughfall is not linearly related to vegetation cover because an increase in cover does not involve a proportional reduction in throughfall. The throughfall predicted by the two-parameter exponential model of Calder (1986) provides a good fit with the observed throughfall and the\gamma\value of the model reflects the evolution of throughfall rate. The soil moisture distribution is modified by fire owing to the increase of evaporation in the surface soil and the decrease of transpiration from deep soil layers. Nevertheless, the use of the old root system by sprouting vegetation leads to a soil water profile in which 20 months after the fire the soil water was similar in burnt and unburnt areas. Overall, soil moisture was higher in burnt plots than in unburnt plots. Surface runoff increased after a fire but did not entirely account for the increase in throughfall. Therefore the removal of vegetation cover in gorse scrub by fire mainly affects the subsurface water flows.

Comment

8-year-old gorse 1.2 m tall. 4plots were burned under 2 fire regimes, 2 were left as controls.

Rainfall and throughfall

	Rainfall (mm)	Throughfall Control (mm)	Throughfall Burn 1 (mm)	Throughfall Burn 2 (mm)
1988–1989	889	519 (58.4)	780 (87.7)	792 (89.1)
1989–1990	1255	725 (59.9)	1020 (81.3)	1019 (81.2)
1990–1991	1517	830 (54.7)	1031 (68.0)	997 (65.7)
1991–1992	1063	606 (57.0)	662 (62.3)	634 (59.6)

4 years after burning throughfall had decreased to a level similar to that of the control plot.

Obtained regressions between storm event rainfall and throughfall.

Control plot	TF = 0.63 × PTTN − 2.50	n = 96	$r^2 = 0.90$
Burn 1: Year 1	TF = 0.94 × PTTN − 1.21	n = 31	$r^2 = 0.97$
Burn 1: Year 2	TF = 0.89 × PTTN − 1.21	n = 28	$r^2 = 0.98$
Burn 1: Year 3&4	TF = 0.63 × PTTN − 2.06	n = 37	$r^2 = 0.93$
Burn 2: Year 1	TF = 0.91 × PTTN − 1.29	n = 31	$r^2 = 0.97$
Burn 2: Year 2	TF = 0.84 × PTTN − 1.63	n = 28	$r^2 = 0.96$
Burn 2: Year 3&4	TF = 0.68 × PTTN − 1.96	n = 37	$r^2 = 0.92$

Increases in surface runoff from the plots following burning were much smaller than the gains in throughfall indicating increased subsurface and groundwater losses.

Plot runoff

	Rainfall (mm)	Runoff Control (mm)	Runoff Burn 1 (mm)	Runoff Burn 2 (mm)
1988–1989	889	3 (4.1)	7 (7.2)	56 (0.3)
1989–1990	1255	46 (3.6)	64 (5.1)	47 (3.9)
1990–1991	1517	23 (1.5)	45 (3.0)	28 (1.9)
1991–1992	1063	28 (2.6)	36 (3.4)	34 (3.2)

(b) Bracken, *Pteridium* spp.

Carlisle, A.; Brown, A.H.F.; White ,E.J.; 1967: The nutrient content of tree stem flow and ground flora litter and leachates in a sessile oak (Quercus petraea) oak woodland. Journal of Ecology 1967 55:615–627.

Country: England	Duration: 4 months	Report Location: R1457
Vegetation: Deciduous forest with bracken understory		
Keywords: Nutrient cycling; Throughfall		

Comment
Sessile oak woodland with bracken and *Deschampia flexuosa* understoreys..

For the bracken community rainfall was measured above the bracken (i.e. under the forest canopy) and under the bracken canopy.

Incident rainfall above the forest in the 4-month period was 584 mm; throughfall was 403 mm and stemflow 31 mm.
Incident rainfall above the bracken was 403 mm, 64 mm was intercepted and 340 mm passed through to the litter.

Lockwood, J.G.; Lyall, D.K.; McDonald, A.T.; Naden, P.S.; Smith, R.T. 1986: Water balance studies in moorland bracken with reference to the changes following bracken clearance. Bracken: Ecology, landuse and control technology. Parthenon Publications. Carnforth, England. P 273–283.

Country: England	Duration: 5 months	Report Location: R1457
Vegetation: Scrubland (Bracken)		
Keywords: Transpiration		

Comment
A bracken water use model is presented based on the Penman-Monteith equation.

Shows bracken canopy transpiration to be up to 3 mm/day but varying during the season as leaf area index changes. Evaporation from the litter is also important.

Pitman, J.I. 1989: Rainfall interception by bracken n open habitats–relations between leaf area index, canopy storage and drainage rate. Journal of Hydrology 105: 317–334.

Country: England	Duration: 5 months	Report Location: R199
Vegetation: Scrubland (Bracken)		
Keywords: Interception		

Comment

A mixture of laboratory work on cut fronds and field plots.
Measured maximum water storage = 0.467 × LAI
Measured minimum water storage when the canopy ceases to drain = 0.156 × LAI

Pitman, J.I.; Pitman, R.M. 1986: Transpiration and evaporation from bracken (*Pteridium aquilinum* L. Kuhn) in open habitats. Bracken: Ecology, landuse and control technology. Parthenon Publications. Carnforth, England. P 259–272.

Country: England	Duration: 3 growing seasons	Report Location: R1456
Vegetation: Scrubland (Bracken)		
Keywords: Evaporation; Transpiration		

Comment

Bracken in the open. Based on data from 3 growing seasons. Noted about 91% of the bracken biomass was underground, 64 % of the root system was in the top 50 cm of soils, and no rhizomes penetrated as far as the Bh horizon (depth not stated).
MAP = 950 mm, PE 550 mm. June to 15 Sept. rainfall 139 to 330 mm.

Evaporation and transpiration rates averaged 1.98 mm/d in 1980 and 2.74 mm/day in 1981, on porometry measurement days. The overall mean was 2.44 mm/day and maximum rates exceeded 5 mm/day.

Interception losses during 1981 accounted for 40.1% of the 1981 precipitation (139 mm).

Supplements this work with the following summary.

Comparison of canopy parameters in different vegetation

	Maximum LAI	Conductance, mm/sec			Evaporation mm/day		
		ks	kc	ka	mean	max	median
Bracken—forest	1	36894	36894	37146	0.51		
Bracken—heathland	5	36961	20–60	5–100	2.5	5.49	2.43
Heather–Yorkshire			37061	10–100	2.3	0.25	1

Heather—Scotland			3.5–20		2	0.3	1.01
Pasture			5–100	10–100	2.1	2.9	
Barley			5–67	5–100	2.1	3.2	
Forest	37112	36898	8–32	50–500			

Pitman, J.I.; Pitman, R.M. 1990: Rainfall interception by bracken canopies and bracken litter. Bracken 1989: Proceedings of an International Conference, Sydney 1989. AIAS Occasional Publ. 40: 153–161.

Country: England	Report Location: Not sighted
Vegetation: Scrubland (Bracken)	
Keywords: Interception	

CAB Abstracts AN 912312316

Previous data on rainfall interception by bracken (*Pteridium* spp.) are critically reviewed. The results of 3 seasons' measurements of throughfall and frond 'stem' flow are presented, as well as laboratory studies on the relationship between bracken leaf area and drainage rate, and bracken litter biomass and drainage rate. The maximum amount of water stored on bracken fronds is a simple function of leaf area, whilst the drainage rate is shown to be a simple exponential function of the amount of water stored when the bracken ceases to drain. The results of field measurements are compared to interception, modelled using the new drainage functions and the Rutter interception model.

Roberts, J. 1986: Stomatal conductance and transpiration from a bracken understorey in a pine plantation. Bracken: Ecology, landuse and control technology. Parthenon Publications. Carnforth, England. P 249–258.

Country: England	Duration: 2 growing seasons	Report Location: R1455
Vegetation: Scrubland (Bracken)		
Keywords: Transpiration		

Comment

Transpiration from bracken and forest during summer 1976

	Forest including understorey (mm)	Bracken (mm)	Bracken/fores t %
37050	2.1	0.51	24
37052	1.8	0.38	21
37055	1.8	0.41	23

37056	1.8	0.35	19
37077	1.9	0.97	51
37080	1.1	0.72	65
37084	1.1	0.66	60
37086	1.3	0.7	54
37106	2.6	1.57	22
37108	1.3	0.56	43
37111	1.5	0.45	30
37113	1.6	0.58	36
37149	0.9	0.19	21
37155	1.3	0.41	31
37175	1.1	0.21	19

Roberts, J.; Pymar, C.F.; Wallace, J.S.; Pitman, R.M. 1980: Seasonal changes in leaf area, stomatal and canopy conductances and transpiration from bracken below a forest canopy. Journal of Applied Ecology 17: 409–422.

Country: England	Duration:	Report Location: R201
Vegetation: Scrubland (Bracken)		
Keywords: Transpiration		

Comment

Measurements on 15 days in 1976—the same table as above for Roberts (1986) is given.

Smith, R.T; Lockwood, J.G. 1990: Bracken invasion and bracken replacement: guidelines for the prediction of hydrological changes. Bracken 1989. Proceedings of an International Conference, Sydney 1989. AIAS Occasional Publ. 40: 175–185.

Country: England	Duration:	Report Location: Not sighted
Vegetation: Scrubland (Bracken)		
Keywords: Interception		

CAB Abstracts AN 912312318

Soil moisture deficits based on field measurements and model simulation for northern England were used to establish that significant differences occur between bracken-covered and other surfaces, vegetated and unvegetated. Clearance of bracken (*Pteridium aquilinum*) initially led to increased soil moisture. Establishment of alternative vegetation led, with the exception of conifers, to higher summer soil moisture deficits. The results are discussed in relation to other areas, and the success of bracken is linked to specific hydrological attributes.

Williams, A.G.; Kent, M.; Ternan, J.L. 1987: Quantity and quality of bracken throughfall, stemflow and litterflow in a Dartmoor catchment. Journal of Applied Ecology 24: 217–230.

Country: England	Duration: 5 months	Report Location: R200
Vegetation: Scrubland (Bracken)		
Keywords: Interception		

Comment
5 months from frond shoot emergence in June until senescence in October.

PTTN: 462 mm; Tf + Sf = 237 mm = 48.7% of precipitation for the period and about 20% of the annual total.

(c) Large catchments

Duncan, S.H. 1986: Peak stream discharge during thirty years of sustained timber management in two fifth order watersheds in Washington State. Northwest Science 60: 258–264

Country: USA	Duration: 30 years	Report Location: R1478
Vegetation: Evergreen native forest		
Land-Use Change: Harvesting		
Keywords: Stormflow		

Comment
23200ha in the 42900 ha Deschutes River watershed in the Cascades mountains, Washington State. Mainly Douglas fir with western hemlock and Pacific silver fir. Continuously harvested over 30 years and at the end of the study 44% of the catchment was < 15 years old. All clearcuts have been regenerated with Douglas fir. Uses the 14200 ha Naselle River catchment as a control.

Selected storms above a given baseflow—67 for the Deschutes and 43 for the Naselle.

Regressed peak flow against total storm rainfall and plotted residuals v time to examine the relationship between increasing clearcut area and peak flow magnitude. A linear relationship gave a better r^2 that a power relationship but less than half the variance could be explained be the relationships. No trends could be seen in the residuals. This indicated that at this catchment scale and the distributed progressive harvesting regime, no effects could be detected.

Lyons, J.K.; Bescheta, R.L. 1983: Landuse, floods and channel changes: Upper Middle Fork Willalete River, Orgeon (1936-1980) Water Resources Research 19:463-471.

Country: USA	Duration: 45 years	Report Location: LKR
Vegetation: Mixed		
Land-Use Change: Harvesting		
Keywords: Storm flow		

Comment
Between 1940 and 1980 about 15% of the 66,800 ha catchment was harvested. MAP is about 1500 mm. For 46 major storms over the last 22 years, they regressed peak flow against total storm rainfall = rainfall on the day of the peak and the previous days to get:
Peak flow (cumecs) = 7.08 x Precip (mm)$^{0.7784}$
But only 38% of the variation in the data was explained by the regression.
Carried out an analysis on the residuals from the regression, which showed a time trend that indicated increasing peak flows.

Patric, J.H.; Gould, E.M. 1976: Shifting landuse and the effects on river flow in Massachusetts. Journal of the American Water and Wastes Association ### 41–45.

Country: USA	Duration: 30 years	Report Location: R1477
Vegetation: Mixed		
Land-Use Change: Afforestation		
Keywords: Water yield		

Comment

Data for several large watersheds on Massachusetts from the mid- to late-1800s to the 1970s. There are non-statistically significant changes apparent in mass curves of annual flows which coincide with significant changes in landuse practices as farms were abandoned and allowed to revert to forest. The changes noted amounted to 50 mm per year but the decreases were not apparent until at least 50% of the watersheds had been afforested by a process of reversion from agriculture.

Pitman, W.V. 1978: Trends in streamflow due to upstream land-use changes. Journal of Hydrology 39: 227–237.

Country: South Africa	Duration: 24 years	Report Location: R1446
Vegetation: Not stated		
Land-Use Change: Afforestation		
Keywords: Water yield		

Comment

Used a model developed by the author to detect a change in streamflow of 4.3 mm/yr as the 20 000 ha Queens River had forestry expansion from 12 to 55% over the study period.

Trimble, S.W.; Weirich, F.H. 1987: Reforestation reduces streamflow in the southestern Unites States. Journal of Soil and Water Conservation 42: 274–277.

Country: USA	Duration: 75 years	Report Location: R1445
Vegetation: Mixed		
Land-Use Change: Afforestation		
Keywords: Water yield		

Comment
Ten watersheds ranging in area from 2820 km^2 to 19450 km^2. Used annual streamflow-rainfall regressions for early and late periods (generally within 1900–1940 and 1955–1975) and double-mass analysis.

Change in streamflow with afforestation, SE USA

Catchment area (km^2)	Area reforested (%)	Decrease from regression (mm (%))	Decrease from mass curve (mm (%))
5800	27.5	36 (8.4)	38 (8.8)
7640	27.5	58 (14.4)	61 (15.1)
4790	25.7	64 (13.6)	48 (10.3)
2820	21.3	99 (21.0)	94 (20.0)
9195	20	38 (6.7)	43 (7.5)
19450	15.4	89 (18.7)	56 (11.8)
4300	11.8	25 (4.7)	28 (5.3)
3030	11	28 (4.0)	61 (8.7)
6500	10.5	66 (16.1)	69 (16.8)
4200	9.7	48 (19.6)	61 (12.3)

Trimble, S.W.; Weirich, F.H.; Boag, B.L. 1987: Reforestation and the reduction of water yield in the southern Piedmont since circa 1940. Water Resources Research 23: 425–437

Country: USA	Duration: 50 years	Report Location: R1340
Vegetation: Mixed		
Land-Use Change: Afforestation		
Keywords: Water yield		

Comment
Presents much the same data as Trimble and Weirich (1987).

Section 5: Additional References

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