# Hydrology of Douglas Fir Plantations/Forests:

# An Annotated Bibliography

# SMF2167: Report No 2

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# Contents

## 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 to assist water and land managers make the best allocations of water resources for all end-users.

Within the project, a series of bibliographies will provide information on hydrological data for Douglas fir (*Pseudotsuga menziesii)* forests and plantations, radiata pine (*Pinus radiata)* plantations, and New Zealand land-use studies.

This report contains information pertaining primarily to Douglas fir plantations and is divided into four 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 four topic areas (hydrological topics, vegetation comparisons, land-use changes, and country of origin) and includes citations relevant to each keyword.
- Section 3 is the bibliography of relevant 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 list of citations referenced in the document but not included in Section 3.

# 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 forests are planted, 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 (Ministry for the Environment (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 be used 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.

**New Zealand plantation forests**

At 1 April 1999, exotic forests covered 1.73 m ha or 6% of New Zealand's land area. At 86 000 ha (5% of the exotic forest estate), Douglas fir (*Pseudotsuga menziesii*) is the most significant species planted after *P. radiata*, and is found mainly in the lower South Island or at higher altitudes, often above 1000 m. Douglas fir is becoming increasing popular in the South Island and is increasing as a percentage of the southern plantation estate (Belton & Law 1996)

About 82 000 ha of other species, including eucalypts, are also grown (NZFI undated).

Between 1992 and 1999, new exotic forest 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 improved (45%) and unimproved (45%) pasture, 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, but for *Pinus radiata* plantations or native forests, not Douglas fir plantations. Apart from Moutere and Ashley, these are higher rainfall areas where concerns about water yields are not high. This is in contrast to Nelson and the east coasts of both islands where water is often scarce in summer and the most relevant data come 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 (SMF2167: Report No 2) focuses on Douglas fir (*Pseudotsuga menziesii*) and is one of a series being prepared for the project. Report No. 1 (Rowe et al. 2001a) is a bibliography of the hydrology of *Pinus radiata*. New Zealand studies on the hydrology of other land uses can be found in Report No. 3 (Rowe et al. 2001b).

Very little information is available on the hydrology of Douglas fir from New Zealand studies. Although a native of North America, Douglas fir can be found in significant-sized plantations in Australia and Europe. Thus, there is potentially a wealth of information to supplement that found from New Zealand sources. Therefore, this bibliography has been compiled from papers and reports obtained from searches of the literature in worldwide databases, mainly using CAB Abstracts, to supplement the few available from New Zealand research, including those in the authors' archives.

A number of the studies report on the differences in water yield between Douglas fir-covered catchments and those with other vegetation covers, e.g., indigenous forests, grasslands, and pasture, while others focus on processes such as interception or transpiration. The focus of the bibliography is hydrology, and papers on water quality and other aspects are listed only when these accompanied useful hydrological data.

## 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, quickflow |
| Throughfall | |
| Transpiration | Dry weather evaporation |
| 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 |

*Species (or Vegetation Class) Comparisons*

| | |
|---|---|
| Douglas fir or Douglas fir/mixed stands only | |
| Conifers | Does not include pine species |
| Eucalypt | Natural forest or plantations |
| Native deciduous forest | |
| Native evergreen forest | Does not include eucalypt species |
| Native grassland | |
| *Pinus radiata* | |
| Pine species | |
| Scrubland (or shrubland) | |

*Land-use Change*

| | |
|---|---|
| Afforestation (includes from scrubland) | |
| Conversion from one forest to another | |
| Fire | |
| Forest management | |
| Harvesting | Of Douglas fir plantations only otherwise in Conversion |
| Insect damage | |

*Country of Origin*

- Australia
- Canada
- England
- France
- Germany
- Italy
- New Zealand
- The Netherlands
- United States
- Unknown

# *Hydrological Topics* Index

Leaf, C.F. 1975
Stednick, J.D. 1996

**Soil water**
Barner, J.; Krahl, W.; Rosenstock, A. 1968
Bouten, W.; Heimovaara, T.J.; Tiktak, A. 1992
Cantore, V.; Iovino, F. 1989
Cinnirella, S. et al. 1993
Cline, R.G.; Haupt, H.F.; Campbell, G.S. 1977
Feller, M C. 1978
Gessel, S.P.; Cole, D.W. 1965
Schaap, M.G.; Bouten, W.; Verstraten, J.M. 1997
van Wijk et al. 2001

**Stemflow**
Aussenac, G.; Boulangeat, C. 1980
Aussenac, G.; Granier, A. 1987
Aussenac, G.; Granier, A.; Naud, R. 1982
Aussenac, G.; Granier, A.; Naud, R. 1984
Duncan, H.P. et al. 1978
Fahey, B.; Watson, A.; Payne, J. 2001
Heuveldop, J.; Mitscherlich, G.; Kunstle, E. 1972
Langford, K.J.; O'Shaughnessy, P.J. 1977
Mitscherlich, G. et al. 1966
Mitscherlich, G.; Moll, W. 1970
Rutter, A.J.; Morton, A.J.; Robins, P.C. 1975

**Storm flow**
Beschta, R.L. et al. 2000
Cheng, J.D. et al. 1975
Fahey, B.; Jackson, R. 1997
Golding, D.L. 1987
Harr, R.D. 1986
Harr, R.D.; Fredriksen, R.L.; Rothacher, J. 1979
Harr, R.D. et al. 1975
Harr, R.D.; Levno, A.; Mersereau, R. 1982
Harr, R.D.; McCorison, F.M. 1979
Harris, D.D. 1973
Harris, D.D. 1977
Jones, J.A. 2000
Jones, J.A.; Grant, G.E. 1996
Rao, S.V.N. 1998
Rothacher, J. 1965
Rothacher, J. 1970
Rothacher, J. 1971
Rothacher, J. 1973
Thomas, R.B.; Megahan, W.F. 1998
Wright, K.A. et al. 1990
Ziemer, R.R. 1981
Ziemer, R.R. 1998

**Throughfall**
Aussenac, G.; Boulangeat, C. 1980
Aussenac, G.; Granier, A. 1987
Aussenac, G.; Granier, A.; Naud, R. 1982
Aussenac, G.; Granier, A.; Naud, R. 1984
Bouten, W.; Heimovaara, T.J.; Tiktak, A. 1992
Bouten, W. et al. 1996
Cole, D.W.; Johnson, D.W. 1977
Draaijers, G.P.J.; van Ek, R.; Meijers, R. 1992
Duncan, H.P. et al. 1978
Fahey, B.; Watson, A.; Payne, J. 2001
Farrell, E.P. et al. 1994
Heuveldop, J.; Mitscherlich, G.; Kunstle, E. 1972
Hogg, S.E.; Murray, D.L.; Manly, B.J.F. 1978
Houdijk, A.L.F.M.; Roelofs, J.G.M. 1991
Kreutzer, K. et al. 1998
Langford, K.J.; O'Shaughnessy, P.J. 1977
Mitscherlich, G.; Moll, W. 1970
Rothacher, J. 1963
Schowalter, T.D. 1999
van Ek, R.; Draaijers, G.P.J. 1994
Will, G.M. 1959

**Transpiration**
Bosveld, F.C.; Bouten, W. 2001
Black, T.A. 1979
Black, T.A.; Tan, C.S.; Nnyamah, J.U. 1980
Cohen, Y.; Kelliher, F.M.; Black, T.A. 1985
Fritschen, L.J.; Doraiswamy, P. 1973
Fritschen, L.J.; Hsia, J.; Doraiswamy, P. 1977
Giles, D.G.; Black, T.A.; Spittlehouse, D.L. 1985
Granier, A. 1987
Kline, J.R. et al. 1976
Swanson, R.H. 1981
van Wijk et al. 2001

**Water balance**
Fahey, B.; Watson, A.; Payne, J. 2001
Riha, S.J.; Campbell, G.S. 1985
Tiktak, A.; Bouten, W. 1994
van Wijk et al. 2001

**Water quality**
Cole, D.W.; Johnson, D.W. 1977
Feller, M.C.; Kimmins, J.P. 1979
Harris, D.D. 1973

## *Species (or Vegetation Class) Comparisons* Index

Harris, D.D. 1977
Helvey, J.D. 1972
Helvey, J.D.; Tiedemann, A.R. 1978
Henderson, G.S. et al. 1978
Heuveldop, J. et al. 1972
Hicks, B.J.; Beschta, R.L.; Harr, R.D. 1991
Hogg, S.E.; Murray, D.L.; Manly, B.J.F. 1978
Ingwersen, J.B. 1985
Jones, J.A. 2000
Jones, J.A.; Grant, G.E. 1996
Kelliher, F.M.; Black, T.A.; Price, D.T. 1986
Keppeler, E.T. 1998
Keppeler, E.T.; Ziemer, R.R. 1990
Kline, J.R. et al. 1976
Kreutzer, K. et al. 1998
Leaf, C.F. 1975
Martin, I.L.; Tinney, E.R. 1962
McNaughton, K.G.; Black, T.A. 1973
Mitscherlich, G. et al. 1966
Nnyamah, J.U.; Black, T.A. 1977
Riha, S.J.; Campbell, G.S. 1985
Rao, S.V.N. 1998
Rothacher, J. 1963
Rothacher, J. 1965
Rothacher, J. 1970
Rothacher, J. 1971
Schaap, M.G.; Bouten, W. 1997
Schaap, M.G. et al. 1997
Schowalter, T.D. 1999
Spittlehouse, D.L.; Black, T.A. 1979
Spittlehouse, D.L.; Black, T.A. 1981
Thomas, R.B.; Megahan, W.F. 1998
Tiktak, A.; Bouten, W. 1994
Wright, K.A.; Sendek, K.H.; Rice, R.M.; Thomas, R.B. 1990
Ziemer, R.R. 1981
Ziemer, R.R. 1998

**Conifers**

Azevedo, J.; Morgan, D.L. 1974
Barner, J.; Krahl, W.; Rosenstock, A. 1968
Bosch, J.M.; Hewlett, J.D. 1982
Duncan, H.P. et al. 1978
Forgeard, F.; Gloaguen, J.C.; Touffet, J. 1980
Langford, K.J.; O'Shaughnessy, P.J. 1977
Rutter, A.J.; Morton, A.J.; Robins, P.C. 1975
Stednick, J.D. 1996
Will, G.M. 1959

**Eucalypts**

Bosch, J.M.; Hewlett, J.D. 1982
Duncan, H.P. et al. 1978
Feller, M C. 1978
Langford, K.J.; O'Shaughnessy, P.J. 1977

**Native deciduous forest**

Aussenac, G.; Boulangeat, C. 1980
Baumgartner, A. 1979
Bosch, J.M.; Hewlett, J.D. 1982
Draaijers, G.P.J.; van Ek, R.; Meijers, R. 1992
Forgeard, F.; Gloaguen, J.C.; Touffet, J. 1980
Granier, A.; Badeau, V.; Breda, N. 1995
Krygier, J.T. 1971
Kunstle, E.; Mitscherlich, G. 1977
Mitscherlich, G.; Moll, W. 1970
Rutter, A.J.; Morton, A.J.; Robins, P.C. 1975
Stednick, J.D. 1996
van Ek, R.; Draaijers, G.P.J. 1994

**Native evergreen forest**

Bosch, J.M.; Hewlett, J.D. 1982
Fahey, B.; Jackson, R. 1997

**Native grassland**

Fahey, B.; Jackson, R. 1997

***Pinus radiata***

Duncan, H.P. et al. 1978
Fahey, B.D. 2000
Fahey, B.; Watson, A.; Payne, J. 2001
Feller, M C. 1978
Langford, K.J.; O'Shaughnessy, P.J. 1977
Swanson, R.H. 1981
Will, G.M. 1959

**Pine species**

Bosch, J.M.; Hewlett, J.D. 1982
Cinnirella, S.; Iovino, F.; Perniola, .G.; Tersaruolo, A.M. 1993
Draaijers, G.P.J.; van Ek, R.; Meijers, R. 1992
Forgeard, F.; Gloaguen, J.C.; Touffet, J. 1980
Fourt, D.F.; Hinson, W.H. 1970
Houdijk, A.L.F.M.; Roelofs, J.G.M. 1991
Kitching, R. 1967
Kunstle, E.; Mitscherlich, G. 1977
Mitscherlich, G.; Moll, W. 1970
Rutter, A.J.; Morton, A.J.; Robins, P.C. 1975

Stednick, J.D.  1996
Swanson, R.H.  1981
van Ek, R.; Draaijers, G.P.J.  1994
Will, G.M.  1959

**Scrubland (or shrubland)**

Bosch, J.M.; Hewlett, J.D.  1982
Duncan, H.P. et al.  1978
Langford, K.J.; O'Shaughnessy, P.J.  1977
Stednick, J.D.  1996

## *Land-use Change* Index

## *Country of Origin* Index

Jones, J.A. 2000
Jones, J.A.; Grant, G.E. 1996
Keppeler, E.T. 1998
Keppeler, E.T.; Ziemer, R.R. 1990
Kline, J.R. et al. 1976
Krygier, J.T. 1971
Leaf, C.F. 1975
Martin, I.L.; Tinney, E.R. 1962
Riha, S.J.; Campbell, G.S. 1985
Rao, S.V.N. 1998
Rothacher, J. 1963
Rothacher, J. 1965
Rothacher, J. 1970
Rothacher, J. 1971
Rothacher, J. 1973
Schowalter, T.D. 1999
Stednick, J.D. 1996
Thomas, R.B.; Megahan, W.F. 1998
Wright, K.A. et al. 1990
Ziemer, R.R. 1981
Ziemer, R.R. 1998

**Worldwide**
Bosch, J.M.; Hewlett, J.D. 1982

**Unknown**
Baumgartner, A. 1979

## Section 3: Bibliography

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

Many of the abstracts 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 versions of 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 correct, 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.

| | | |
|---|---|---|
| Country: | Duration: | Report Location: |
| Species Comparison: | | |
| Land-Use Change: | | |
| Stand Type: | Stand Density: | Basal Area: |
| Height: | Diameter: | Rainfall: |
| Keywords: | | |

Note: A negative age implies pre-planting or calibration data are available

**Abbreviations**

Abbreviations used in the tables and *Comments* (may be in lowercase or uppercase) are:

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

**Units**

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

**Aussenac, G.; Boulangeat, C. 1980: Rainfall interception and actual evapotranspiration in broadleaved (*Fagus sylvatica*) and coniferous (*Pseudotsuga menziesii*) stands. (Interception des precipitations et evapotranspiration reelle dans des peuplements de feuillu (*Fagus sylvatica* L.) et de resineux (*Pseudotsuga menziesii* (Mirb) Franco)). Annales des Sciences Forestieres 37: 91–107.**

| | | |
|---|---|---|
| Country: France | Duration: < 1 yr | Report Location: LKR |
| Species Comparison: Native deciduous forest | | |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 11 & 23 yr | Stand Density: See below | Basal Area: See below |
| Keywords: Evaporation; Interception; Stemflow; Throughfall | | |

*CAB Abstracts AN 800666498/Author's summary*

Interception and evapotranspiration were assessed in an 11-yr-old Douglas fir stand (3086 stems/ha), three 23-yr-old Douglas fir stands (530, 1030 and 2229 stems/ha) and an 80-yr-old beech stand (743 stems/ha). In winter, interception was 6% of the rainfall in the beech stand vs. 32–36% in the 23-yr-old Douglas fir stands. In summer, interception increased in the beech stand (21%), but remained constant in the Douglas fir stand. In spring before flushing, beech stand evapotranspiration was lower than that of the Douglas fir stand, but was the same in summer. The evapotranspiration of the lower density Douglas fir stand was lower than that of the others (18% vs. 27%).

*Comment*
It appears that the winter data quoted in the abstract are for 1 month (October) and summer for one month (July)

Interception storage capacity:

Douglas fir for 23 yr and 535 SPH 3.6± 0.7 mm
Douglas fir for 23 yr and 1030 SPH 3.7 ± 0.8 mm
Douglas fir for 23 yr and 2229 SPH 3.9 ± 0.8 mm
Beech for 80 yr and 743 SPH 1.7 ± 0.5 mm

**Water balance 13 July to 24 October 1978**

| Stand | PTTN (mm) | TF (mm) | SF (mm) | IL (mm) | ET (mm) | Potential ET (mm) | ET/PET |
|---|---|---|---|---|---|---|---|
| Douglas fir 535 SPH | 148 | 89 | 3 | 59 | 172 | 230 | 0.75 |
| Douglas fir 1030 SPH | 148 | 81 | 10 | 67 | 211 | 230 | 0.92 |
| Douglas fir 2229 SPH | 148 | 76 | 14 | 72 | 211 | 230 | 0.92 |
| Douglas fir 3086 SPH | 148 | 96 | 11 | 52 | 218 | 230 | 0.94 |
| Beech 743 SPH | 148 | 114 | 3 | 34 | 208 | 230 | 0.91 |

Notes decreasing throughfall, increasing stemflow and more or less constant interception with stand density.

Shows data for a number of studies relating interception to stand age (his Fig. 7).

**Aussenac, G.; Granier, A. 1987: Effects of thinning on water stress and growth in Douglas fir. Canadian Journal of Forest Research 18: 100–105.**

| Country: France | Duration: 5 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 19 yr | Stand Density: 2932 & 1447 SPH | Basal Area: 39 & 20 $m^2$/ha |
| Height: 11.5 m | Diameter: 39.9 cm | Rainfall: MAP 700 mm |
| Keywords: Evaporation; Interception; Stemflow; Throughfall | | |

*Comment*
This is the same stand as that in Aussenac et al. (1982, 1984), which was thinned at age 19 yr in 1980. The stand was thinned (alternate rows were taken out) in February 1980. This paper reports measurements of growth and soil water during 5 yr after thinning. These are not full years of rainfall as MAP is about 700 mm.

Rainfall in 1981 was high intensity, in 1983 it was light hence the differences in the percentages listed. 'Thinning resulted in a 17% increase in ET in 1980. This effect rapidly vanished and, in 1984, 5 yr after thinning, the ET of the 2 stands was nearly similar'.

The soil water data show a gradual decline in the difference between the control and thinned sites that emerged a few months after thinning. Total evapotranspiration from the thinned stand was 0.83 of that from the control in the summer (June–October) of 1980 and this ratio increased each year reaching 1.03 in 1984. Variability of soil water was high in the thinned stand in 1980, but by 1984 it had decreased to equal the control indicating that roots of the remaining trees now fully occupied the site.

**Interception in 19–24-yr-old Douglas fir**

| Stand | PTTN (mm) | Throughfall mm (%) | Stemflow mm (%) | Interception mm (%) |
|---|---|---|---|---|
| Unthinned 1980 | 388 | 178 (46) | 42 (11) | 169 (43) |
| Thinned 1980 | 388 | 240 (62) | 31 (8) | 118 (30) |
| Unthinned 1981 | 382 | 265 (69) | 65 (17) | 119 (31) |
| Thinned1981 | 382 | 296 (77) | 46 (12) | 189 (23) |
| Unthinned1983 | 53 | 19 (36) | 2 (4) | 32 (61) |
| Thinned 1983 | 53 | 25 (46) | 2 (3) | 27 (52) |

**Evaporation from 19–24 year-old Douglas fir**

| Period | Precipitation (mm) | ET unthinned (mm) | ET thinned (mm) | ET thinned/ ET unthinned |
|---|---|---|---|---|
| 24 July – 7 Oct.1980 | 111 | 182 | 152 | 0.83 |
| 17 June – 29 Sept 1982 | 258 | 291 | 266 | 0.92 |
| 1 June – 29 Sept.1982 | 355 | 423 | 402 | 0.95 |
| 6 July – 24 Oct.1983 | 128 | 213 | 200 | 0.94 |
| 18 June – 27 Aug. 1984 | 66 | 152 | 126 | 1.03 |

'Thinning resulted in a 17% increase in ET in 1980. This effect rapidly vanished and, in 1984, 5 yr after thinning, the ET of the 2 stands was nearly similar'.

**Aussenac, G.; Granier, A; Naud, R. 1982: Influence of thinning on growth and water balance of a young plantation of Douglas fir *(Pseudotsuga menziesii* (Mirb.) Franco). Influence d'une eclaircie sur la croissance et le bilan hydrique d'un jeune peuplement de Douglas *(Pseudotsuga menziesii* (Mirb.) Franco)). Canadian Journal of Forest Research 12: 222–231.**

| Country: France | Duration: 5 months | Report Location: LKR |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 19 yr | Stand Density: 2932 and 1447 SPH | Basal Area: 39 and 20 $m^2$/ha |
| Height: 11.5 m | Diameter: 39.9 cm | Rainfall: MAP 700 mm |
| Keywords: Evaporation; Interception; Stemflow; Throughfall | | |

*CAB Abstracts*

A 19-yr-old Douglas fir plantation near Nancy, France, was thinned to alternate rows. The incident light reaching ground level was increased from less than 1% in the control to 7.3% in the thinned stand; light reaching the crown bases was increased from 1% to 17.6%. Effects on temperature and vapour pressure were slight. Thinning reduced interception of precipitation from 43.4% to 30.3%; evapotranspiration was reduced by 16.7%. One yr after thinning, the BA of the thinned stand was 101% that of the unthinned stand. In the thinned stand, foliage dry wt. in the lower whorls of the crown was 13–31% greater than in the unthinned stand because of fewer old needles dropping.

*Comment*

**Interception in 19-yr-old Douglas fir — 5 months**

| Stand | PTTN (mm) | Throughfall mm (%) | Stemflow mm (%) | Interception mm (%) |
|---|---|---|---|---|
| Unthinned | 388 | 178 (46) | 42 (11) | 169 (43) |
| Thinned | 388 | 240 (62) | 31 (8) | 118 (30) |

**Water balance 24 June – 2 October**

| Stand | PTTN mm | IL mm | SM change mm | ETR mm |
|---|---|---|---|---|
| Unthinned | 111 | 46 | −71 | 182 |
| Thinned | 111 | 32 | −40 | 152 |

ETR = Precipitation minus change in soil moisture

**Aussenac, G.; Granier, A.; Naud, R. 1984: Systematic thinning in a young Douglas fir stand: microclimatic changes and effects on growth. (Eclaircie systematique dans un jeune peuplement de Douglas: modifications microclimatiques et influences sur la croissance). Revue Forestiere Francaise. 36: 279–288.**

| | | |
|---|---|---|
| Country: France | Duration: 5 months | Report Location: LKR |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 19 yr | Stand Density: 2932 and 1447 SPH | Basal Area: 39 and 20 $m^2$/ha |
| Height: 11.5 m | Diameter: 39.9 cm | Rainfall: MAP 700 mm |
| Keywords: Evaporation; Interception; Stemflow; Throughfall | | |

*CAB Abstracts*

The study was carried out in the Amance State Forest in a 19-yr-old Douglas fir stand. A systematic thinning in Feb. 1980 removed one row in two, with one plot left unthinned as a control. Thinning considerably increased girth increment from the first growing season after thinning. This was associated with increased photosynthetic productivity, resulting from a 15% increase in foliage and an increased photosynthetic rate in needles that had previously been in the shade. Opening of the canopy increased by 2 m the zone of illumination favourable to photosynthesis. Growth was significantly increased throughout the growing season, as a result of increased light and a considerable improvement in the water supply (increased interception and water reserves). Thinning particularly encouraged the growth of codominant trees.

*Comment*

Although not explicit in the abstract, data are provided on interception and evaporation: the same data as in the tables in Aussenac et al. (1982).

**Azevedo, J; Morgan, D.L. 1974: Fog precipitation in coastal California forests. Ecology 55: 1135–1141.**

| | | |
|---|---|---|
| Country: United States | Duration: 46 days | Report Location: LKR |
| Species Comparison: Conifers | | |
| Stand Type: Various-aged forests | | |
| Keywords: Fog | | |

*Comment*

Included for completeness. Up to 430 mm of throughfall collected from fog.

**Barner, J.; Krahl, W.; Rosenstock, A. 1968: Winter soil moisture under Japanese larch and Douglas fir. Allgemeine Forstzeitung 23: 600–601.**

| Country: Germany | Report Location: Not sighted |
|---|---|
| Species Comparison: Conifers | |
| Stand Type: Plantation 11 yr | |
| Keywords: Interception; Soil water | |

*CAB Abstracts AN: 3000067*

Briefly describes the hydrological research area near Freiburg and discusses first results of a study in which winter soil-moisture storage and infiltration were compared for 11-yr-old Douglas fir and Japanese larch established at 2 × 2-m. spacing on comparable sites. Total winter precipitation, interception, evaporation from the ground, and seepage (determined by lysimeter-cf. F.A. 27 No. 3283) were measured. Evaluation after the end of snow-melt showed that the larch, although the canopy was more closed than that of the Douglas fir, was hydrologically superior. Soil seepage was up to three times that in Douglas Fir, in which the evergreen branches intercepted much snow. Morphological differences between races (branching angle etc.) affected not only snow interception and winter soil moisture, but also summer interception and evaporation from the ground.

**Baumgartner, A. 1979: Evapotranspiration in the forest. (Verdunstung im Walde).** ***In:*** **Gunther, K. H. (Compiler), Forests and water: development and present position. (Wald und Wasser : Entwicklung und Stand.) Schriftenreihe des Deutschen Verbandes fur Wasserwirtschaft und Kulturbau 41: 39–53.**

| Country: Unknown | Report Location: Not sighted |
|---|---|
| Species Comparison: Native deciduous forest | |
| Keywords: Evaporation; Interception | |

*CAB Abstracts AN: 800661913*

A description of the contributions of transpiration from trees, evaporation of rainfall intercepted by tree crowns and evaporation from the forest floor and ground flora. Beech and Douglas fir lose little water by transpiration, whereas birch and oak lose a much larger amount. Evaporation of intercepted water is lower in broadleaves than conifers. Forests have a higher total evapotranspiration than land used for other purposes.

*Comment*

Not sighted but may contain useful data.

**Beschta, R.L.; Pyles, M.R.; Skaugset, A.E.; Surfleet, C.G. 2000: Peakflow responses to forest practices in the western Cascades of Oregon, USA. Journal of Hydrology 223: 102–120.**

| Country: United States | Report Location: R1566 |
|---|---|
| Land-Use Change: Forest management; Harvesting | |
| Stand Type: Natural forest | |
| Keywords: Storm flow | |

*Comment*
Western Cascades, Oregon. Small catchments: HJ Andrews Watersheds 1 (96 ha),2 (control) and 3 (101 ha); Six large (62–637 $km^2$) catchments.

This paper is one of a number of papers (Jones & Grant 1996; Thomas & Megahan 1998; Jones 2000; and published comments) debating the responses of catchment peak flows to forest management.

In the small catchments, peakflow increases were dependent upon peakflow magnitude, were 13–16% for 1-yr recurrence intervals events and 6–9% for 5-yr events.

For the large catchments, results were mixed. Half the analyses gave significant results, but the explained variance due to harvesting was only 1–7%.

**Black, T.A. 1979: Evapotranspiration from Douglas fir stands exposed to soil water deficits. Water Resources Research 15: 164–170.**

| Country: Canada | Duration: June – August for 2 yr | Report Location: R143 |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 20 yr | Stand Density: 1840 and 840 SPH | |
| Height: 7–10 m | | |
| Keywords: Evaporation; Transpiration | | |

*CAB Abstracts/Authors' Abstracts*

The rate of evapotranspiration from thinned and unthinned stands of Douglas fir was measured using energy and water balance methods. At high values of soil water storage in the root zone the evapotranspiration rate was approximately 80% of the equilibrium evaporation rate. Below a critical value of soil water storage the ratio of the evapotranspiration rate to the equilibrium evaporation rate (E/Eeq tended to decrease linearly with decreasing soil water storage. The critical values of soil water storage in the root zone were 11.8 and 8.3 cm for the thinned and unthinned stand, respectively. Below these critical storage values, there was approximately 3.5 cm of water remaining in both root zones that was extractable by the trees. The relationship between E/Eeq and the fraction of extractable water in the root zone for both stands was very similar for sunny days. In this relationship, E/Eeq began to decrease when there was approximately 40% of the extractable water remaining in the root zones of both stands.

*Comment*
Measurements were made at the unthinned site in 1974 and at the thinned site in 1975.
Soils were up to 85 cm deep over sandstone.

At the beginning of a dry spell (30 June) daily ET at site 2 (thinned) was 3–4 mm/day and fell to 0.75 – 1.75 mm/day by end of July. The previous year ET for a comparable period (the first 10 days after rain) at the site 1 (unthinned) stand was lower but the weather was cloudier. The ratios of latent heat flux to net radiation for the 10 days after rain at the two sites were similar: site 1 at 53% and site 2 at 49%.

**Black, T.A.; Kelliher, F.M. 1989: Processes controlling understorey evapotranspiration. Philosophical Transactions of the Royal Society of London Series B, Biological Sciences 324: 207–231.**

| Country: Canada | Duration: July–September | Report Location: R48 |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 31 yr | Stand Density:800 SPH | |
| Keywords: Evaporation | | |

*CAB Abstracts AN 910647693/Authors' Abstract*
Understorey often accounts for a significant proportion of forest evapotranspiration. The role is discussed of understorey radiation regime, and aerodynamic and stomatal conductance characteristics of the understorey in understorey evapotranspiration. Values of the McNaughton- Jarvis parameter OMEGA for understorey in two mid-rotation Douglas fir stands indicate considerable coupling between understorey and atmosphere above the overstorey. However, stronger coupling between overstorey and atmosphere accounts for the observation that the fraction of stand evapotranspiration originating at the understorey increases as water vapour pressure deficit increases and the soil dries. Approaches to describing the process of evaporation from the forest floor are also discussed. The results of understorey removal experiments show small decreases in stand evapotranspiration and root-zone soil water content, but significant increases in transpiration and growth of the trees.

*Comment*

**Modelled components of water balance — 24 July to 3 September**

| | Overstorey | | Understorey | | | |
|---|---|---|---|---|---|---|
| Understorey | Transpiration (%) | Interception (%) | Transpiration (%) | Interception (%) | Soil (%) | Total (mm) |
| Present | 44 | 17 | 32 | 3.5 | 3.5 | 88 |
| Removed | 63 | 19 | — | — | | 81 |

Noted that 'rather than an accumulation of moisture in the root zone as a result of understorey removal, most of the additional water was taken up by the trees.'

**Black, T.A.; Tan, C.S.; Nnyamah, J.U. 1980: Transpiration rate of Douglas fir trees in thinned and unthinned stands. Canadian Journal of Soil Science 60: 625–631.**

| Country: Canada | Duration: June — August for 2 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 22 yr | Stand Density: 1840 and 840 SPH | |
| Height: 7–10 m | | |
| Keywords: Evaporation; Transpiration | | |

*CAB Abstracts AN: 811960072*

A procedure is described for estimating the transpiration rate of trees in stands with understorey vegetation. The procedure combines soil water balance measurements of stand evapotranspiration rate with a simple vapour diffusion model that requires occasional intensive measurements of stomatal conductance of the trees and understorey vegetation. Weekly average transpiration rates of 22-yr-old Douglas fir trees in a thinned stand during sunny weather in July ranged from 23.6 L/tree/day when theta e, the fraction of extractable soil water remaining in the root zone, was 0.79 to 4.9 L/tree/day when theta e was 0.20. The transpiration rate of trees in the thinned stand, which contained a salal understorey, was very similar to that in a nearby unthinned stand with virtually no understorey vegetation. As theta e decreased from slightly more than 0.8 to slightly less than 0.2, the fraction of evapotranspiration from the thinned stand due to the salal understorey increased from approximately 40 to 65%. Competition for soil water by the understorey was considered to be a contributing reason why tree diameter growth in the thinned stand was only slightly greater than in the unthinned stand.

*Comment*

Same stand as Black (1979).

Measurements were made at the unthinned site in 1974 and at the thinned site in 1975; Thinning occurred in 1974 to May 1975.

Soils were up to 85 cm deep over sandstone.

**Mean daily stand (including understorey) and tree evaporation**

| Period | θ | Net radiation (mm) | Stand evaporation (mm) | Es/Rn | Tree evaporation (L/tree) | Et/Rn |
|---|---|---|---|---|---|---|
| 1974 Unthinned | | | | | | |
| 18–28 July | 0.6 | 5.5 | 2.9 | 0.53 | 15.8 | 2.87 |
| 28 July–4 Aug. | 0.4 | 6.4 | 2.5 | 0.39 | 13.6 | 2.13 |
| 4–11 Aug. | 0.3 | 6.1 | 1.9 | 0.31 | 10.3 | 1.69 |
| 11–17 Aug. | 1.1 | 4.9 | 1 | 0.2 | 5.4 | 1.1 |
| 1975 Thinned | | | | | | |
| 1–6 July | 0.8 | 7.4 | 3.6 | 0.49 | 23.6 | 3.16 |
| 6–11 July | 0.6 | 6.9 | 3.4 | 0.49 | 20.2 | 2.93 |

| Period | θ | Net radiation (mm) | Stand evaporation (mm) | Es/Rn | Tree evaporation (L/tree) | Et/Rn |
|---|---|---|---|---|---|---|
| 11–18 July | 0.4 | 1.5 | 2.3 | 0.51 | 12 | 2.67 |
| 18–25 July | 0.3 | 5.2 | 1.8 | 0.35 | 8.2 | 1.58 |
| 25 July–1 Aug. | 0.2 | 5.2 | 1.2 | 0.23 | 4.9 | 0.94 |

θ is the fraction of extractable water remaining in the root zone.

Transpiration of individual trees in the thinned stand with thick understorey was similar to those in the unthinned stand with virtually no understorey. The thinned stand had greater evaporation because of greater radiation and also the high (50%) consumption by the salal understorey.

**Borghetti, M; Vendramin, G.G. 1987: Seasonal changes of soil and plant water relations in Douglas fir forest. Acta Oecologica, Oecologia Plantarum 8: 113–126.**

| | | |
|---|---|---|
| Country: Italy | Duration: 9 months | Report Location: LKR |
| Stand Type: Plantation 26 yr | Stand Density: 2044 SPH | Basal Area: 41.7 $m^2$/ha |
| Height 14.2 m | | Rainfall: MAP 1248 mm |
| Keywords: Evaporation | | |

*CAB Abstracts AN: 870618950*

Measurements of sapwood relative water (Rs) content and soil water potential (psis) were performed throughout the 1985 growing season in a 26-yr-old Douglas fir plantation in the Apennines, Italy. Evapotranspiration, twig water potential (psit) and stomatal conductance were measured periodically. From April to Sept. Rs decreased from 87.4 to 38.5%, which corresponds to a water depletion of 9.3 mm. In the same period psis decreased from −0.007 to −0.992 MPa between 30 and 60 cm depth. Between May and Sept. the contribution of sapwood water storage to evapotranspiration was 1.9%. The maximum contribution from sapwood water storage to evapotranspiration (11.2%) occurred between mid- and end Aug. An increase of Rs of 15.4% was observed between mid- and end June. Predawn twig water potential (psip) varied from −0.675 MPa in mid-June to −1.064 MPa at the end of Sep., with a maximum value of −0.409 MPa in mid-July. Over most of the sampling period psis was considerably greater than psip. psit was always lower in the upper crown level. In general psit decreased during the morning, reaching a minimum value around noon, and increased during the afternoon. No threshold level of psit for stomatal closure occurred, even when psit was as low as −1.7 MPa.

*Comment*:
On average ET was 2.8 mm/day between Julian days 108 and 276.

**Bosch, J.M.; Hewlett, J.D. 1982: A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology 55: 3–23.**

| | |
|---|---|
| Country: Worldwide | Report Location: R34 |
| Species Comparison: Conifers; Eucalypt forests; Native deciduous forests; Native evergreen forests; Scrubland | |
| Land-Use Change: Afforestation; Conversion; Harvesting | |
| Keywords: Review; Water yield | |

*CAB Abstracts*

This summary and review of 94 catchment experiments shows that accumulated information on the effect of vegetation changes on water yield can be used for practical purposes. The direction of change in water yield following forest operations can be predicted with fair accuracy since no experiments, with the exception of perhaps one, have resulted in reductions in water yield with reductions in cover, or increases in yield, with increases in cover. The approximate magnitude of changes can also be estimated. Pine and eucalypt forest types cause on average 40 mm change in water yield per 10% change in cover and deciduous hardwood and scrub ~25 and 10 mm, respectively. Maximum changes of 660 mm were experienced at Coweeta, North Carolina. An assimilation of the collective experimental results shows that more careful design and expansion of experiments to certain rainfall regions would augment statistical inference.

**Bosveld, F.C.; Bouten, W. 2001: Evaluation of transpiration models with observations over a Douglas fir forest. Agricultural and Forest Meteorology 108: 247–264.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 43 dry days | Report Location: LKR |
| Stand Type: Plantation 17 yr | Stand Density: 785 SPH | |
| Diameter: 21 cm | | Rainfall: MAP 800 mm |
| Keywords: Models; Transpiration | | |

*Comment*

The stand had an LAI of 11. Tested Jarvis (1976), Monteith (1995) and Priestley-Taylor models against eddy-correlation data fro 43 dry days in April to September..

‘The Jarvis formulation and the Monteith formulation performed almost equally well. .......... The Priestley-Taylor model performed somewhat worse which was to be expected given the lack of canopy response in such a formulation.’

**Bouten, W.; Heimovaara, T.J.; Tiktak, A. 1992: Spatial patterns of throughfall and soil water dynamics in a Douglas fir stand. Water Resources Research 28: 3227–3223.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 1.5 yr | Report Location: R148 |
| Stand Type: Plantation 30 yr | Stand Density: 885 SPH | |
| Diameter: 21 cm | | Rainfall: MAP 800 mm |
| Keywords: Soil water; Throughfall | | |

*CAB Abstracts AN 931975731*

The spatial patterns of throughfall and soil physical properties were assessed at the ACIFORN research location near Garderen, The Netherlands. Measured spatial patterns of water uptake were related to measured throughfall patterns around Douglas fir trees, particularly in dry months. The one-dimensional soil water model SWIF (Soil Water in Forested Ecosystems), which is used to describe vertical water flow and root water uptake in the unsaturated soil zone, was modified to a quasi-three-dimensional model allowing preferential water uptake from wet sites. The model was used to describe the impact of spatial patterns on the spatial distribution of soil water dynamics in terms of water contents, pressure heads, root water uptake and vertical fluxes. The results suggested that the spatial distribution of yearly water uptake and percolation fluxes was strongly influenced by throughfall patterns and soil water contents were primarily dependent on soil physical properties.

*Comment*

Interception losses are as high as 40% of PTTN. Stemflow was never observed.

**Bouten, W.; Schaap, M.G.; Aerts, J.; Vermetten, A.W.M. 1996: Monitoring and modelling canopy water storage amounts in support of atmospheric deposition studies. Journal of Hydrology 181: 305–321.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 9 months | Report Location: LKR |
| Stand Type: Plantation 27 yr | Stand Density: 785 SPH | |
| Height: 18 m | Diameter: 21 cm | Rainfall: MAP 800 mm |
| Keywords: Throughfall | | |

*CAB Abstracts AN 961905442*

Canopy water storage amounts were measured with a system based on the attenuation of a 10.26-GHz microwave signal. The study was carried out in a Douglas fir plantation in The Netherlands. Every 5 min, vertical scans were made, over a period of 9 months. A physically based multi-layer interception model with empirical parameters was calibrated using a non-linear optimisation technique. The calibrated model was capable of explaining up to 92% of the measured variance of water storage amounts for an independent validation period when using on-site measurements of meteorological variables. The performance decreased to 89% when other input sets were used for this period. These were necessary to extrapolate the results to longer time series required for evaluating canopy resistances in the study of deposition of airborne pollutants.

*Comment*

Canopy interception storage capacity was calculated to be in the range 2.07 to 2.58 mm.

Does not give actual measured throughfall. However, shows the fit of simulated v measured weekly throughfall amounts. States that the simulated amounts match the measured amounts (the regression relationship was not different from the 1:1 line) therefore the following table should be close to real values. The interception model developed here explains over 99% of the variation in the weekly throughfall data. The two sets of data correspond to using different reference raingauges.

**Simulated throughfall for 27-yr Douglas fir**

| | Clearing raingauge | Tower raingauge | All values |
|---|---|---|---|
| Precipitation (mm) | 751 | 379 | 1130 |
| Throughfall (mm) | 426 | 217 | 643 |
| TF/PTTN (%) | 57 | 57 | 57 |

**Cantore, V.; Iovino, F. 1989: Thinning effects on soil moisture in Douglas fir stands in the Coast Range (Calabria). (Effetti dei diradamenti sull'umidita del suolo in popolamenti di douglasia della Catena Costiera (Calabria)). Incremento della produzione di legno con specie agrarie e forestali a rapido accrescimento. Sottoprogetto 'Conifere' [coordinated by Ciancio, O.]. Annali dell'Istituto Sperimentale per la Selvicoltura 20: 13–39.**

| | | |
|---|---|---|
| Country: Italy | Duration: Two summers | Report Location: Not sighted |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 21 yr | Stand Density: Various | |
| Keywords: Soil water | | |

*CAB Abstracts AN: 920656240*

Relations between different thinning regimes — control (1645 trees/ha), three intensities of selective thinning (equivalent to Hart-Becking ratios 17, 18 and 19), systematic thinning (1 row out of 3), and mixed systematic/selective thinning - and soil moisture during the period of summer drought were investigated. Thinning was carried out in May 1986 of a 21-year-old Douglas fir stand situated in an experimental forest near Cosenza, S. Italy (900–1000 m altitude, W.-facing, sandy soils). Soil moisture deficits were measured in June–October 1988 and 1989. In general, results showed that selective thinning improved soil moisture, compared with control or systematically thinned plots: mean soil moisture content was between 6% and 11% greater (A horizon) in 1988 and 1989, respectively.

**Cheng, J.D.; Black, T.A.; de Vries, J.; Willington, R.P.; Goodell, B.C. 1975: The evaluation of initial changes in peak streamflow following logging of a watershed on the west coast of Canada. International Association of Hydrological Sciences Publication 117: 475–486.**

| Country: Canada | Duration: 3 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Natural forest | Stand Density: Various | |
| Keywords: Storm flow | | |

*Comment*

UBC Research Forest Watersheds 1 and 2 at Haney. Douglas fir one of four main species.

Looked at peak flow (PF, maximum flow less initial baseflow, $m^3/sec/km^2$ and time to peak (TP, hours) after harvesting watershed 1.

Before logging

| | | |
|---|---|---|
| TP1 = 0.9569 + 0.7808 × TP2 | n = 21 | $r^2 = 0.9648$ |
| PF1 = −0.0412 + 1.3593 × PF2 | n = 21 | $r^2 = 0.9940$ |

After logging

| | | |
|---|---|---|
| TP1 = 2.8181 + 1.0066 × TP2 | n = 22 | $r^2 = 0.9553$ |
| PF1 = −0.0125 + 1.0194 × PF2 | n = 22 | $r^2 = 0.9540$ |

**Flow parameters before and after clear-cutting**

| | Time to peak (hours) | | Peak flow ($m^3/sec/km^2$) | |
|---|---|---|---|---|
| | Watershed 1 | Watershed 2 | Watershed 1 | Watershed 2 |
| Mean before | 12.3 | 14.5 | 0.414 | 0.335 |
| Range before | 4.0–28.0 | 4.3–36.0 | 0.089–1.542 | 0.085–1.130 |
| Mean after | 20.2 | 17.3 | 0.392 | 0.398 |
| Mean before | 8.0–45.0 | 4.0–41.0 | 0.124–1.015 | 0.127–1.008 |

In both cases the changes in slope are significantly different — intercepts were not tested. These changes were contrary to most studies as there was an increase in time to peak and a decrease of peak flows. Attributed this to a change in flow pathways as the hydrographs were flattened (were unable to test for stormflow volumes) as the disturbances on watershed 1 would not have been favourable to cause the changes observed.

**Cinnirella, S.; Iovino, F.; Perniola, .G.; Tersaruolo, A.M. 1993: Effect of thinning on soil moisture content. (Efficacia dei diradamenti sulla riserva idrica del solo.) Progetto finalizzato MAF 'Arboricoltura da legno', sottoprogetto 'Conifere'. Annali dell'Istituto Sperimentale per la Selvicoltura. 24: 7–22.**

| Country: Italy | Duration: 3 yr | Report Location: Not sighted |
|---|---|---|
| Species Comparison: Pine species | | |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 24 yr | Stand Density: Various | |
| Keywords: Soil water | | |

*CAB Abstracts AN: 990601945*

Studies were undertaken into the effect of stand thinning on soil moisture content in 24-yr-old Douglas fir stands, and in 33- to 52-year-old Calabrian pine (*Pinus nigra* var. *calabrica*) stands, located on different soil types in Calabria (the Coast Range, pre-Sila, Sila Grande and Sila Greca), S. Italy. Measurements were taken between June and October in 1990, 1991 and 1992 (for a Douglas fir in the Coast Range) and in 1992 for all other stands. In 1990 and 1991 the gravimetric method was used to determine soil moisture content. In 1992, in contrast, the time domain reflectometry (TDR) technique was employed. For all sites, data collected in unthinned plots were compared to those from plots that had been thinned from below several years previously to different grades: light, medium, heavy and (for the Calabrian pine stand in the Pre-Sila only) very heavy thinning. Results indicate that the more intense the thinning, the greater the effect on soil moisture content. The greatest differences were observed between heavyily and very heavily thinned plots. Mean percentage increases (by volume) of soil water for these two extreme thinning grades were from 3 to 8% for surface soil layers, and from 5 to 14% for deeper soil horizons. Data from the Douglas fir stand also indicate that this thinning effect is retained over time.

**Cline, R.G.; Haupt, H.F.; Campbell, G.S. 1977: Potential water yield response following clearcut harvesting on north and south slopes in northern Idaho. USDA Forest Service Research Paper, Intermountain Forest and Range Experiment Station No. INT-191. 16 p.**

| Country: United States | Duration: 1 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Natural forest | | |
| Keywords: Soil water | | |

*CAB Abstracts AN: 780648472*

Total precipitation, net precipitation (that which percolated through the snowpack or entered the soil as the snowpack melted), potential evapotranspiration and soil water contents were monitored in 1972–73 in plots in the forest and in small areas clear-felled in 1968 and 1969 on (a) a south-facing slope with an overstorey predominantly of Douglas fir with 20–30% crown closure and (b) a north-facing slope with an overstorey predominantly of *Tsuga heterophylla* with 90–100% crown closure. On some of the clear-felled plots the vegetation was in the process of recovering and on others the vegetative cover was removed. The north-facing revegetated plot had the lowest rate of evapotranspiration of all the revegetated or forested plots in June–Aug., when the soil profiles contained least water. Minimum soil water content was greater on the N.- than on the south-facing slope; that of the revegetated plot was greater than that of the forested plot on the north-facing slope, whereas on the south-facing slope the water contents in the revegetated and forested plots were equal. The north-facing clear-felling showed an increase of 19.6 cm of total percolate compared with the forested plot while the south-facing clear-felling showed an increase of only 2.9 cm. Less snow storage and lysimeter percolate occurred in the north-facing forest than in the south-facing forest.

*Comment*
Mostly a response to differing snow accumulations on plots in uncut forests and forest clear-cuts.

**Cohen, Y.; Kelliher, F.M.; Black, T.A. 1985: Determination of sap flow in Douglas fir trees using the heat pulse technique. Canadian Journal of Forest Research 15: 422–428.**

| | | |
|---|---|---|
| Country: Canada | Duration: 3 days in July–Sept | Report Location: LKR |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 21 & 31 yr | Stand Density: Various | |
| Keywords: Evaporation; Transpiration | | |

*CAB Abstracts AN 850603495/Authors' Abstract*

A modified heat pulse technique was used to determine volumetric sap flow in 15–17-m tall trees in the University of British Columbia Research Forest. Laboratory calibration of the heat pulse technique, accomplished by passing water through 200 × 77 mm stem sections with a gas pressure apparatus, showed an underestimation of the actual water flow rate by 47%. Using a 6-thermistor temperature-sensing probe inserted radially to a depth of 60 mm, field measurements of sap flux density were found to change with depth into the sapwood. Simultaneous measurements using the temperature-sensing probes inserted in three azimuthal directions (0, 120, and 240°) showed good agreement during the daytime in three trees, while in another tree the ratio of the three sap flux densities gradually changed during the daytime. Hourly values of sap flow rate in two different trees, obtained using the laboratory calibration factor, were 29 and 53% larger than corresponding foliar transpiration rates estimated using measurements of stomatal conductance, tree leaf area and vapour pressure deficit. Using a microprocessor-based data acquisition system, the technique was successfully used to monitor the course of sap flow rate over a 4-month period.

*Comment*
23-yr-old stand, 1100 SPH, 17.5 m tall, DBH 19.0 cm.
Late September, clear day, transpiration 1.9 mm/day. Previous data from this stand 8 yr earlier indicated transpiration 1.5 to 2.5 mm/day on a clear day. Noted sapflow measurements were larger than foliar transpiration.

**Cole, D.W.; Johnson, D.W. 1977: Atmospheric sulfate additions and cation leaching in a Douglas fir ecosystem. Water Resources Research 13: 313–317.**

| Country: United States | Duration: 2 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Second growth | | |
| Keywords: Throughfall; Water quality | | |

*Comment*

Mean of 2 yr data:

Annual PTTN = 1400 mm; TF = 1100mm; beneath forest floor = 900 mm, beneath A horizon = 800 mm; below B horizon = 700 mm.

**Draaijers, G.P.J.; van Ek, R.; Meijers, R. 1992: Research on the impact of forest stand structure on atmospheric deposition. Environmental-Pollution 75: 243–249.**

| Country: The Netherlands | Duration: April – July | Report Location: LKR |
|---|---|---|
| Species Comparison: Native deciduous forest; Pine species | | |
| Stand Type: Plantation 40–60 yr? | | |
| Height: 11–24 m | | |
| Keywords: Throughfall | | |

*CAB Abstracts AN 930665866/Authors' Abstracts*

Dry and wet deposition onto 30 forest stands in central Netherlands in relation to stand structure was studied by sampling throughfall and bulk precipitation. Nine measurement sites were situated in Douglas fir stands, 10 in *Pinus sylvestris* and 11 in *Quercus robur* stands. All stands were situated within a radius of 1.2 km to assure a more or less equal air pollution load. In each stand, detailed forest structure inventories were made to determine aerodynamic roughness, collecting efficiency and surface area parameters. Measurements covered a 4-month period (April–July 1990). First results showed relatively high throughfall deposition in Douglas fir stands. Lowest throughfall fluxes were recorded for *Q. robur* and intermediate values for *P. sylvestris* stands. There were indications of a relatively strong canopy exchange in *Q. robur* stands during the measurement period. Many results from forest stand structure inventories are not yet available. However, a strong relation was observed between throughfall deposition in Douglas fir stands and total crown volume.

*Comment*

**Throughfall**

| | PTTN (mm) | Throughfall Douglas fir | Throughfall *Pinus sylvestris* | Throughfall *Quercus robur* |
|---|---|---|---|---|
| Amount | 164 | 124.3 | 131.6 | 137.2 |
| SD (for five samples) | 9.6 | 18 | 7.4 | 8.5 |

**Duncan, H.P.; Langford, K.J.; O'Shaughnessy, P.J. 1978: A comparative study of canopy interception. Institution of Engineers, Australia, National Conference Publication 78/9: 150–154.**

| Country: Australia | Duration: 8 yr | Report Location: Landcare Library |
|---|---|---|
| Species Comparison: Conifers; Eucalypts; *Pinus radiata*; Scrubland | | |
| Stand Type: Plantation 40–48 yr | Stand Density: 668 SPH | Basal Area: 55 $m^2$/ha |
| Height: 30.2 m | | |
| Keywords: Interception; Stemflow; Throughfall | | |

*Comment*
Coranderrk, Victoria.
Weekly sampling:
TF = PTTN × 0.604 − 0.72
SF = PTTN × 0.161 − 0.60
IL = PTTN × 0.235 + 1.32

**Interception summary**

| | Throughfall (%) | Stemflow (%) | Interception loss (%) |
|---|---|---|---|
| Mixed species | 75.4 | 1.3 | 23.3 |
| Hazel | 73.2 | 12 | 14.8 |
| Mature ash | 72.5 | 4.3 | 23.2 |
| Regrowth ash | 76 | 5.3 | 18.7 |
| Musk | 75.1 | | |
| Redwood | 59.8 | 1.1 | 39.1 |
| *P. radiata* | 68 | 10.6 | 21.4 |
| Douglas fir | 58 | 14.1 | 27.9 |

Note: Rainfall amounts are not given in this paper.
Throughfall was smaller for Douglas fir than under redwood, *P. radiata* and eucalypt species but stemflow was greater.
Interception loss by Douglas fir was less than that of redwood but greater than that of all other species.

**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 (Nov. – Aug.) | Report Location: LKR |
|---|---|---|
| Species Comparison: *Pinus radiata* | | |
| Stand Type: Plantation: 18 & 54 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. 1997: 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 |
|---|---|---|
| Species Comparison: Native evergreen forest; Native grassland | | |
| Land-Use Change: Afforestation; Conversion from one forest to another | | |
| Stand Type: Plantation −2–15 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 dealt with the conversion of mixed evergreen forest (dominated by beech, *Nothofagus truncata* and *N. fusca)* to pine (*P. radiata* with some Douglas fir) plantation in NW 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 examined 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*
Included only because a minor amount of Douglas fir had been planted at one site. 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% clear-felling of DC1 streamflow increased 312 mm/yr (61%) and at the 94% cleared DC4 the yield was 344 mm/yr higher (90%). (These are proportionally equivalent to 375 and 365 mm on a 100% clear-felling basis — LKR). After this, there was a decline in flows to preharvest levels after about 8 yr.
Low flow comparisons 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). There were fewer storms at GH2 than at GH1 in 1991–1993. 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.; 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 |
|---|---|---|
| Species Comparison: *P. radiata* | | |
| Stand Type: Plantation 18 & 54 yr | Stand Density: various | Basal Area: various |
| 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 |

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 |

**Farrell, E.P.; Cummins, T.; Collins, J.F.; Beier, C.; Blanck, K.; Bredemeier, M.; de Visser, P.H.B.; Kreutzer, K.; Rasmussen, L.; Rothe, A.; Steinberg, N. 1994: A comparison of sites in the EXMAN project, with respect to atmospheric deposition and the chemical composition of the soil solution and foliage. Forest Ecology and Management 68: 3–14.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 3 yr | Report Location: LKR |
| Stand Type: Plantation 35 to37 yr | Stand Density: 992 SPH | Basal Area: 30 $m^2$/ha |
| Height: 18 m | Diameter: 20 cm | Rainfall: MAP 850 mm |
| Keywords: Throughfall | | |

*CAB Abstracts AN: 950602603/Authors' Abstracts*

Forest stands, throughfall and the composition of the soil solution in six coniferous forest plantations in Europe were compared as part of the EXMAN project (EXperimental MANipulation of forest ecosystems in Europe), which was established to quantify biogeochemical cycles and the effects of atmospheric deposition on coniferous forest ecosystems. The sites are: Klosterhede, Denmark (*Picea abies*); Kootwijk (Douglas fir) and Harderwijk (*Pinus sylvestris*), Netherlands; Hoglwald and Solling (*P. abies*), Germany; and Ballyhooly (*P. abies*), Republic of Ireland. Even though the EXMAN stands and sites are broadly similar, they represent a wide range of climatic conditions and levels of pollutant deposition. The EXMAN project incorporates treatment of forest plots and in this paper the untreated control plots are compared. The results show marked differences in ionic composition of water between sites, most clearly expressed in throughfall fluxes. At the German and Dutch sites, ionic inputs demonstrate a strong human influence. Throughfall at the Danish and Irish sites is dominated by ions of marine origin. Hydrogen ions are not the most important cations in precipitation at any site, and at only one site (Solling) was the hydrogen ion flux in throughfall greater than in precipitation. The influence of atmospheric deposition on the composition of the soil water is very evident for most major ions. Exceptions to this are ammonium and nitrate, the complexity of whose behaviour demonstrates the need for greater understanding of nitrogen transformation and uptake in coniferous forest ecosystems.

*Comment*

EXMAN project: Does give information for other species in other countries. Not given here as precipitation regimes will be different

3-yr mean annual PTTN 858 mm; Throughfall 544 mm.
Stemflow does not appear to have been measured.

**Feller, M C. 1978: Nutrient movement into soils beneath eucalypt and exotic conifer forests in southern central Victoria. Australian Journal of Ecology 3: 357–372.**

| Country: Australia | Duration: 2 yr | Report Location: LKR |
|---|---|---|
| Species Comparison: Eucalypts; *Pinus radiata* | | |
| Stand Type: Plantation 62 yr | Stand density: 1330 SPH | |
| Height: 20 m | Diameter: 19.9 cm | |
| Keywords: Soil water | | |

*CAB Abstracts AN: 791951505*

Above-ground nutrient return to the soil was estimated by studying forest floor leachates for 2 yr in two eucalypt forests (*Eucalyptus obliqua*) and *E. regnans*) and two nearby conifer plantations (*Pinus radiata* and Douglas fir) near Narbethong in southern central Victoria. Forest floor leachate volumes were recorded and samples were analysed for pH and potassium, sodium, magnesium and calcium concentrations. The volume of forest floor leachate was greater in the eucalypts. This was attributed to greater interception losses of water by the conifers. In each of the four forest types, leachate acidity was highest in spring and autumn and lowest in summer. Cation concentrations were highest in autumn and lower in spring. This behaviour was attributed to changes in climate and in rates of litter decomposition. Cation quantities entering the soil in leachates showed no pronounced seasonal variations but were significantly higher in *E. obliqua* than in *P. radiata*. Greater quantities of acid were added to the soil under *P. radiata*. The *P. radiata* soil contained lower quantities of exchangeable cations than the *E. obliqua* soil but the Douglas fir soil did not appear to be depleted in exchangeable cations.

*Comment*:

**Forest floor leachate, Victoria**

| | May–Dec 1976 | 1978 | Jan–Jul 1977 |
|---|---|---|---|
| Rain (mm) | 608 | 927 | 820 |
| *E. regnans* (units?) | 123 | 134 | 143 |
| *E obliqua* (units?) | 118 | 130 | 154 |
| *P. radiata* (units?) | 88 | 97 | 123 |
| Douglas fir (units?) | 75 | – | – |

Rainfall site is 5 km away.
Leachate values were given as volumes in centimetres but this is inconsistent with the rainfall.
Trend is: ER ~ EO > PR > PM.

**Feller, M.C.; Kimmins, J.P. 1979: Chemical characteristics of small streams near Haney in southwestern British Columbia. Water Resources Research 15: 247–258:**

| Country: Canada | Duration: 2 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Regrowth forest 100 yr | | |
| Keywords: Water quality; Water yield | | |

*Comment*
Flows were measured from two watersheds.

**Annual flows from watersheds in British Columbia**

| | | 1971–1972 | | | 1973–1973 | | |
|---|---|---|---|---|---|---|---|
| Catchment | Area (ha) | PTTN (mm) | RO (mm) | ET=PTTN – RO (mm) | PTTN (mm) | RO (mm) | ET=PTTN – RO (mm) |
| A | 23.1 | 2670 | 1700 | 970 | 1820 | 1010 | 810 |
| C | 44 | | | | 2040 | 1040 | 1000 |

There is assumed to be a groundwater flow of between 150 and 400 mm/yr passing under the weirs.

**Forgeard, F.; Gloaguen, J.C.; Touffet, J. 1980: Interception of precipitation and supply of minerals to the soil by rainfall and rain-water leachates in an Atlantic beach forest and in some coniferous stands in Brittany. (Interception des precipitations et apport au sol d'elements mineraux par les eaux de pluie et les pluviolessivats dans une hetraie atlantique et dans quelques peuplements resineux en Bretagne.) Annales des Sciences Forestieres 37: 53–71.**

| Country: France | Duration: 3 yr | Report Location: LKR |
|---|---|---|
| Species Comparison: Conifers; Native deciduous forest; Pine species | | |
| Stand Type: Plantation 20–22 yr | Stand Density: 2530 SPH | Basal Area: 36 $m^2$/ha |
| Height: 13 m | Diameter: 42 cm | Rainfall: MAP 810 mm |
| Keywords: Interception | | |

*CAB Abstracts AN: 800664079*

Measurements were taken in eight coniferous stands of different species and in a mature beech stand during 1973, 1974 and 1975. The interception study was continued in 1976 and 1977 in seven developmental stages (from thicket to mature timber) of the beech forest. Interception by conifers was greater than that of beech for the same basal area per hectare. The amount of interception by the beech was dependent on stand structure and not age. The amount of interception by conifers varied seasonally, being lower in spring and summer, whereas for beech there was no relation to season; this is explained by seasonal differences in the type of rainfall cancelling out canopy differences in beech. Rainfall carried more Na in the winter; seasonal variations were not detected for other elements. Rainfall supplied 68 kg/ha of mineral elements annually. Throughfall had a greater concentration of minerals than rainfall, the concentration varying according to mineral elements and species. Annual mineral supply by throughfall was greater for beech forest (146 kg/ha) than for coniferous forest (87.5–138 kg/ha). Minerals in stemflow were 21 kg/ha for beech, 3.5–20 kg/ha for conifers.

*Comment*
Monthly interception for Douglas fir ranged from 2.6% to 71.6% with a mean over 3 yr of 51.2%. This was similar to three pines and an *Abies* stand, less than two *Picea* species but greater than for *Tsuga*. Interception by *Fagus sylvatica* was considerably lower at about 18–35%.

It was stated there was a seasonal effect with higher interception losses in winter. The normal experience indicates this is the wrong way around. Would be useful to see the actual data and not just percentages to confirm this. No rainfall data were given to extend the analysis of this data set further.

**Fourt, D.F.; Hinson, W.H. 1970: Water relations of tree crops: a comparison between Corsican Pine and Douglas fir in south-east England. Journal of Applied Ecology 7: 295–309.**

| | | |
|---|---|---|
| Country: England | Duration: 5 yr | Report Location: |
| Species Comparison: Pine species | | |
| Stand Type: Plantation 40–44 yr | Stand Density: 642 SPH | Basal Area: 14.3 $m^2$/ha |
| Height: 23.7 m | | |
| Keywords: Evaporation | | |

*CAB Abstracts AN 3202172*

Further work [cf. F.A. 27 No. 106], the annual cycle of water movement has been studied over five growing seasons in adjacent semi-mature stands of Corsican Pine and Douglas fir, growing on deep porous soils in Bramshill Forest, Hampshire. Periods of soil water deficit in the two stands have been identified from records of gypsum-block resistance measurements of soil moisture tension. Rainfall over this period has been equated with total evaporation and compared with values of open-water evaporation calculated from climatic records. Estimates have been made of water use by the two species, and the site factors affecting these estimates BIOLOGY-ODC 18 269 have been examined. It is concluded that Corsican Pine, which dries the soil more deeply and intensely than Douglas fir, uses more water during the period of deficit. The causes of these differences are not fully understood, but it is possible that wind may interact with the distinctive canopy structure and leaf pattern of the species and thereby affect transpiration, though the rates of loss of intercepted rainfall seem to be similar. There may be differences in the rate of uptake of water as affected by rooting pattern, and in its subsequent movement to the transpiring surfaces, and the effects of the bracken understorey and humus layers should also be considered.

*Comment*
Results suggest that evaporation was less from Douglas fir plantation compared to the Corsican pine, perhaps by 40%.
Not able to determine rates from the data presented.

**Fredriksen, R.L. 1972: Nutrient budget of a Douglas-fir forest on an experimental watershed in**

**western Oregon. *In*: Franklin, J.F.; Dempster, L.J.; Waring, R.H. *ed.* Research on Coniferous Forest Ecosystems: First year progress in the Coniferous Forest Biome, US/IBP. USDA Forest Service , Pacific Northwest Forest and Range Experiment Station. Portland Oregon. Pp. 115–131.**

| Country: United States | Duration: 2 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Old growth forest—450 yr | | |
| Keywords: Nutrient cycling; Water yield | | |

*Comment*
Andrews Experimental Forest, Oregon. Watershed no ?, 10.1 ha

**Streamflow**

| Year | 1969 | 1970 |
|---|---|---|
| Rainfall | 2510 | 1700 |
| Streamflow | 2150 | 1350 |

**Fritschen, L.J.; Doraiswamy, P. 1973: Dew: an addition to the hydrologic balance of Douglas fir. Water Resources Research 9: 891–894.**

| Country: United States | Duration: 2 days | Report Location: R263 |
|---|---|---|
| Stand Type: Single tree in a lysimeter in a regenerating ~ 45-yr stand | | |
| Height: 28 m | | |
| Keywords: Dew; Evaporation; Transpiration | | |

*CAB Abstracts AN 740616623*

A study was made of the hydrologic balance of a single Douglas fir tree (height 28 m) [in Washington], by means of a weighing lysimeter for two clear days in May 1972. The results indicated dew accumulations of 6.4 and 10.9 litres for the two days, which represent 15 and 20% respectively of the total evaporation from the tree. Since the dew was recorded as a weight increase, its source must be the atmosphere. In the Pacific Northwest, conditions are favourable for dew formation during most of the summer and autumn, and thus dew formation could play a large part in the hydrologic balance of fir forests.

*Comment*
These daily totals are equivalent to 0.37 and 0.63 mm; cf. evaporation = 2.43 and 3.16 mm/day, respectively.

**Fritschen, L.J.; Hsia, J.; Doraiswamy, P. 1977: Evapotranspiration of a Douglas fir determined with a weighing lysimeter. Water Resources Research 13: 145–148.**

| Country: United States | Duration: 643 days over 3 yr | Report Location: R298 |
|---|---|---|
| Stand Type: Single tree in a lysimeter in a regenerating ~ 45-yr stand | | |
| Height: 28 m | | |
| Keywords: Evaporation; Transpiration | | |

*CAB Abstracts AN 771933517*

The evapotranspiration (ET) of a 28-m Douglas fir in a weighing lysimeter located on the Cedar River watershed near Seattle, Washington, was determined during the summer and fall of 1972, 1973, and 1974. Average ET rates from the area of the crown projection were 1.8 mm/day or 14.7 gal./day in 1972, 2.0 mm/day in 1973, and 2.5 mm/day in 1974. The range for monthly periods was 1.3–3.6 mm/day. During 1972, ET was 46% of precipitation plus irrigation (P + I), and evaporation of interception (i) was 36% of ET. Comparable values for 1973 were 51% and 37% and for 1974 were 69% and 24%. The lower ET/(P + I) values in 1973 and 1974 were associated with soil moisture depletion studies and longer periods of clear skies. The relatively high i/ET percentages suggest the need for more interception studies. Problems such as irrigation, drainage, listing, wind, rainfall interception, and the translation of data to an area basis that are associated with large plants in lysimeters are discussed.

*Comment*

Stemflow was small and ignored.

**Gessel, S.P.; Cole, D.W. 1965: Influence of removal of forest cover on movement of water and associated elements through soil. Journal American Water Works Association, New York 57: 1301–1310.**

| Country: United States | Duration: | Report Location: Not sighted |
|---|---|---|
| Stand Type: Plantation — 35 yr | | Basal Area: |
| Keywords: Soil water | | |

*CAB Abstracts AN 2705223*

A study of (a) a 35-year-old Douglas fir plantation (BA 163 sq. ft./acre, crown density 90%) in the Cedar River valley, Washington, on a gravelly, loamy, excessively drained sand, and (b) a recently clear-felled plot of the same stand, using an automatically recording system of small-scale tension lysimeters. Their collection plates, 95 sq. in. in size, were placed (a) 1 in. below the forest floor, and (b) 36 in. below, i.e. below the main rooting zone. Ca. 45 % of total precipitation was recorded at (2) in (a), and ca. 74% in (b), representing 12.7 in. of water in the study year. Movement of elements (leachates), at (1) and (2) respectively, increased in (b) as follows (in lb./acre/year): N, from 4.29 to 9.9 and 0.56 to 0.99; K, 8.94 to 15.75, and 0.91 to 1.02; and Ca 14.86 to 19.96 and 4.01 to 8.25, but in no case did the amount at (2) exceed 1 % of the total content of the soil (< 0.05 for N). The increase in release was greatest immediately after clear felling. Movement of elements was greatest at the beginning of the wet season in Sept. and Oct., and fluctuated most for Ca. [Cf. F.A. 27 No. 5535.]

**Giles, D.G.; Black, T.A.; Spittlehouse, D.L. 1985: Determination of growing season soil water deficits on a forested slope using water balance analysis. Canadian Journal of Forest Research 15: 107–114.**

| | | |
|---|---|---|
| Country: Canada | Duration: May to Dec for 2 yr | Report Location: R 529 |
| Stand Type: Even-aged stand 70 yr | Stand Density: Variable | Basal Area: Variable |
| Rainfall: MAP 2100 mm | | |
| Keywords: Evaporation; Interception; Model; Transpiration | | |

*CAB Abstracts AN 850603239/Authors' Abstract*

Coefficients for the calculation of soil water balance components at seven sites on a forested (mostly 70-yr-old Douglas fir) slope on Vancouver Is. were determined using only measurements of daily solar irradiance, maximum and minimum air temp. and rainfall, and weekly root zone soil water content during a 2-yr period (1980–81). Site parameters required were root zone depth, soil water retention characteristics, and rainfall interception coefficients. Based on daytime net radiation, the Priestley-Taylor evapotranspiration coefficient (alpha) was found to be 0.73 ± 0.07, which is similar to values reported in other conifer forest studies. Growing season water deficit increased with decreasing root zone water storage capacity, which was mainly a function of root zone depth. A comparison between sites at high and low altitudes on the slope showed 100-yr site indices ranging from 17 to 53 m correlating (as an inverse linear function) with growing season soil water deficits of 79.4 mm (in the drier year of 1981) or 55.0 mm (in 1980). Annual basal area increments correlated with soil water deficits and with growing season transpiration, both for the study period and when both variables were averaged over the last 18 yr.

*Comment*

The seven plots covered a transect from very xeric to hygric soil moisture classes.

**Growing season water balance — average of 7 plots (LKR)**

| Year | Precipitation (mm) | Soil water deficit (mm) | Transpiration (mm) | Interception (mm) | Soil moisture changes (mm) |
|---|---|---|---|---|---|
| 1980 | 291 | 15 | 299 | 64 | −94 |
| 1981 | 354 | 34 | 288 | 68 | −64 |

**Golding, D.L. 1987: Changes in streamflow peaks following timber harvest of a coastal British Columbia watershed. International Association of Hydrological Sciences Publication 167: 509–517.**

| | | |
|---|---|---|
| Country: Canada | Duration: 14 yr | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: Old growth forest | | |
| Rainfall: MAP 3525 mm | | |
| Keywords: Storm flow | | |

*Comment*
Paired catchments experiment: control catchment 120 ha; treatment catchment 299 ha; 19% of the catchment harvested over 6 yr.
Used mass curve analysis to determine change of peak flows for non-snowmelt and snowmelt storms with >5 mm of precipitation. The years were not identified to look at the responses in more detail. The significant increase in accumulated winter peaks was much greater that the increase in accumulated summer peaks. However this was matched by similar increases in accumulated peak flows from the control catchment. The changes, therefore, are an artifact of a changing precipitation regime.
Makes the point that harvesting 19.2% of the catchment has resulted in 'an increase in treatment-induced peak winter flows to a maximum of 13.5% but no significant change in peak summer flows'. Does not present the data though.

**Granier, A. 1987: Evaluation of transpiration in a Douglas-fir stand by means of sap flow measurements. Tree-Physiology 3: 309–319.**

| | | |
|---|---|---|
| Country: France | Duration: 101 days | Report Location: LKR |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 24 yr | Stand Density: 1384 & 2545 SPH | Basal Area: 31 & 45.2 $m^2$/ha |
| Height: 17.5 m | | |
| Keywords: Evaporation; Transpiration | | |

*CAB Abstracts AN 880623803*

Sap flow was calculated from the temperature difference between two probes inserted into the sapwood, one of which was heated. Measurements were recorded hourly from 29 May to 24 Sep. 1984 on five trees each in control and thinned plots in a 24-yr-old stand in the forest of Amance, near Nancy, France. Variation in sap flow between trees depended on crown class. On a sunny day, total transpiration was 1.6, 8.0 and 22.0 L/day for suppressed, average and dominant trees, respectively. Transpiration estimated by sap flow fell below potential evapotranspiration when available soil water decreased to below 30% of its maximum value. Sap flow measurements gave transpiration values similar to those obtained by the water balance method.

*Comment*

| | |
|---|---|
| Unthinned stand: | maximum transpiration rate 3.6 mm/day |
| Thinned stand: | maximum transpiration rate 2.5 mm/day |

Total seasonal transpiration from Julian day 167 to 267(Southern Hemisphere equivalent is 350 to 85) = 169 mm & 117 mm for unthinned and thinned plots.
When there is little water stress, $E = -0.11 + 0.60 \times PET$ $r^2 = 0.94$,
where PET = daily potential evapotranspiration
Trees became water stressed when relative extractable water (REW) was < 0.30 in the first 60 cm of soil.
Shows relationship between actual and potential evapotranspiration against REW.

**Granier, A.; Badeau, V.; Breda, N. 1995: Modelling the water balance in forest stands. (Modelisation de bilan hydrique des peuplements forestiers). Revue Forestiere Francaise 47: Numero special: 59–68.**

| Country: France | Report Location: LKR |
|---|---|
| Species Comparison: Native deciduous forest | |
| Keywords: Model | |

*CAB Abstracts AN 960605021*

An iterative model is described, which was used to simulate water balance in forest trees, using data for *Quercus petraea*, *Fagus sylvatica* and Douglas fir stands in France. The model illustrates the close relationship between precipitation, soil water balance, water stress and increment for forest trees.

**Harr, R.D. 1976: Forest practices and streamflow in western Oregon. *In*: Symposium on Watershed Management. USDA Forest Service General Technical Report PNW-GTR-49.**

| Country: United States | Report Location: Not sighted |
|---|---|
| Stand Type: Old-growth forest | |
| Keywords: Harvesting; Water yield | |

*Comment*

Not in New Zealand. Some information presented in Stednick (1996)

**Harr, R.D. 1980: Streamflow after patch cutting in the Bull Run watersheds. USDA Forest Service Research Paper PNW-286.**

| | |
|---|---|
| Country: United States | Report Location: Not sighted |
| Stand Type: Old-growth forest | |
| Keywords: Harvesting; Water yield | |

*Comment*
Not in New Zealand.

**Harr, R.D. 1982: Fog drip in the Bull Run Municipal Watershed, Oregon. Water Resources Bulletin 18: 785–789.**

| | | |
|---|---|---|
| Country: United States | Duration: 40 weeks | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: Old-growth forest and 10-yr-old second growth | | |
| Height: Old growth 46–55 m; Second growth 1–1.5 m | | |
| Keywords: Fog; Water yield | | |

*CAB Abstracts AN 830687227 / Author's abstract*

Net precipitation under old-growth Douglas fir forest totalled 1739 mm during a 40-wk period in 1979–80, 387 mm more than in adjacent areas clear-felled 10 yr earlier. Expression of data on a full water year basis and adjustment of gross precipitation for losses due to rainfall interception suggested that fog drip could have added 882 mm of water to total precipitation during a year when precipitation measured in a nearby clearing was 2160 mm. Thus standard rain gauges installed in open areas where fog is common may be collecting up to 30% less precipitation than would be collected in the forest. Timber harvest in the watershed could in the long term reduce annual water yield and, more importantly, reduce summer streamflow by reducing fog drip.

*Comment*
Included for interest as enhanced precipitation through fog interception is not a major factor in New Zealand studies.

**Harr, R.D. 1986: Effects of clearcutting on rain-on-snow runoff in Western Oregon: A new look at old studies Water Resources Research 22: 1095–1100.**

| | |
|---|---|
| Country: United States | Report Location: LKR |
| Land-Use Change: Harvesting | |
| Stand Type: Old-growth forest and up to 10–15-yr-old regrowth | |
| Keywords: Storm flow | |

*Comment*
The paper reports on rain-on-snow events, which occur in many US situations. Data are reported for HJ Andrews Experimental Forest watersheds HJA1, 2, 9 and10. Reviews and updates studies by Rothacher (1973) and Harr & McCorison (1979). Results from one updated study, Rothacher's, 'suggest that clear-cut logging has altered snow accumulation and melt enough to have increased the size of peak flows caused by snowmelt during rainfall.' The other updated study was less conclusive. He also cautions 'Care must be used in selecting published reports to support a particular position in the logging-snowmelt question.'

**Harr, R.D.; Fredriksen, R.L.; Rothacher, J. 1979: Changes in streamflow following timber harvest in southwestern Oregon. US Department of Agriculture, Forest Service Research Paper PNW-249. 22 p.**

| Country: United States | Duration: 14 yr | Report Location: R1320 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Mixed forest | | Rainfall: MAP 1230 mm |
| Keywords: Stormflow; Water yield | | |

*Comment*
Coyote Creek experimental watersheds, Oregon. Vegetation is mixed conifers with Douglas fir, pines and cedar. Mixed ages.

Mean PTTN 1145 mm; mean annual runoff from control (CC-4) = 627 mm (55%)
Increase in streamflow after harvesting. Highest increases in winter and autumn but biggest percentage increases in summer (at CC-3, 2.2 mm = 196%) and spring. Largest increases were in wetter years when of least benefit to downstream users.
A reduction in the flow increase was noticeable the third year.
Peak flows (<2.2 L/sec/ha) increased after harvesting — the change was tested using regression relationships with the control catchment data.

**Changes at Coyote Creek after harvesting Douglas fir**

| | CC-1 | CC-2 | CC-3 |
|---|---|---|---|
| Area (ha) | 69.2 | 68.4 | 49.8 |
| Area harvested (%) | 100 | 30 | 100 |
| Type of cut | Shelterwood cut (50% of BA removed) | Patchcut | Clear-cut |
| Increase in flow years 1–5 | 1–9 mm | 7–12 mm | 23–36 mm |

**Harr, R.D.; Harper, W.C.; Krygier, J.T.; Hsieh, F.S. 1975: Changes in storm hydrographs after road building and clear-cutting in the Oregon Coast Range. Water Resources Research 11: 436–444.**

| Country: United States | Duration: 7 yr | Report Location: R147 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Mixed forest with Douglas fir | | Rainfall: MAP 2500 mm |
| Keywords: Storm flow | | |

*Comment*
Alsea Watershed Study, Oregon.

**Alsea watershed treatments**

| | Deer Creek | DC sub-watershed 2 | DC sub-watershed 3 | DC sub-watershed 4 | Needle Branch | Flynn Creek |
|---|---|---|---|---|---|---|
| Area (ha) | 303 | 56 | 40 | 16 | 70 | 202 |
| Treated (ha) | 87 (29%) | 18 (33%) | 31 (65%) | 14 (95%) | 61 (86%) | 0 |
| Vegetation Douglas fir % | 60 | ? | ? | ? | ? | 30 |

Used rainy season storm events only and Hewlett & Hibbert (1967) method of flow separation. Data separated by season (September–November = autumn recharge period & December–March = winter recharged period). For some analyses the data were separated when antecedent storm baseflow reached 0.38 L/s/ha.

Storm peaks: An increase after roading was observed only at DC3 where roads occupied 12% of the area — +0.5 L/s/ha. After harvesting, average storm peak increases were: DC3 (65%) 0.3 L/s/ha and 1.3 L/s/ha in autumn and winter, respectively; DC 4 (95%) 3 L/s/ha in autumn; Needle Branch (86%) 1.7 and 1.1 L/s/ha in autumn and winter, respectively.

Storm volumes: Only at Needle Branch in autumn did storm volumes (quickflow + baseflow during the storm) increase—total for the period = 66 mm.

Quickflow: Changes were variable. There was a decrease at Deer Creek after road building (autumn and winter)and again after harvesting (autumn) and an increase at Needle Branch after harvesting (in autumn)

Delayed flow: Volumes generally increased after roading and at all sites after harvesting

**Harr, R.D.; Krygier, J.T. 1972: Clearcut logging and low flows in Oregon coastal watersheds. Oregon State University, Forest Research Laboratory Research Note No. 54. 3 p.**

| | | |
|---|---|---|
| Country: United States | Duration: 14 yr | Report Location: R1319 |
| Land-Use Change: Harvesting | | |
| Stand Type: Mixed forest with 120-yr Douglas fir | | Rainfall: MAP 1230 mm |
| Keywords: Low flow | | |

*CAB Abstracts AN 750623024*

Clear-felling the whole of one catchment (covered with pure and mixed stands of Douglas fir and *Alnus rubra*) in the Alsea River basin markedly decreased the number of days with minimum streamflow during the next 5 yr, and hence increased the average minimum streamflow by ca. 60%. The differences occurred in the spring and autumn and occasionally after summer storms. No trend towards the flow values recorded before logging was evident at the end of the period. A smaller effect was observed in a second catchment of which 25% was felled; a third catchment was used as a control.

*Comment*

Alsea Watershed Study, Oregon.

Used a regression relationship on the annual number of low flow days (< 1 cfs/mile$^2$ = 0.1093 L/s/ha = 0.94435 mm/day).

At Deer Creek (25% cut) the effects was only significant in 2 of the 5 yr after cutting.

**Harr, R.D.; Levno, A.; Mersereau, R. 1982: Streamflow changes after logging 130-year-old Douglas fir in two small watersheds. Water Resources Research 18: 637–644.**

| | | |
|---|---|---|
| Country: United States | Duration: | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: 130-yr-old forest | | |
| Keywords: Low flow; Storm flow; Water yield | | |

*CAB Abstracts/AN 830685365*

Felling in two small catchment areas in western Oregon increased annual water yield by up to 42 cm in the first year after harvest. Average yield increases of the first 4 yr were 38 cm in a 13-ha clear-felled catchment and 20 cm in a 15.4-ha catchment where a shelterwood felling removed 60% of basal area. Increased summer streamflows were indicated by many fewer low-flow days, especially in the clear-felled catchment. Neither the size nor the timing of peak flows changed significantly after logging in either catchment.

*Comment*
HJ Andrews Experimental Forest watersheds HJA-6, 7 and 8.

**Streamflow (mm) at experimental watersheds**

| Year | PTTN (mm) | HJA-6 | HJA-7 | HJA-8 |
|---|---|---|---|---|
| 1964 | 2040 | 1320 | 950 | 1150 |
| 1965 | 2730 | 1700 | 1280 | 1570 |
| 1966 | 1720 | 1040 | 680 | 880 |
| 1967 | 1880 | 1170 | 820 | 1070 |
| 1968 | 2160 | 1100 | 720 | 1000 |
| 1969 | 2310 | 1740 | 1210 | 1540 |
| 1970 | 1990 | 1250 | 890 | 1150 |
| 1971 | 2820 | 1940 | 1300 | 1750 |
| 1972 | 2810 | 2310 | 1620 | 1900 |
| 1973 | 1600 | 720 | 550 | 680 |
| 1974 | 2900 | 2530 | 1710 | 2140 |
| 1975 | 2160 | 1960 | 1260 | 1350 |
| 1976 | 2570 | 2090 | 1420 | 1480 |
| 1977 | 1250 | 730 | 470 | 420 |
| 1978 | 2440 | 1920 | 1280 | 1350 |
| 1979 | 1750 | 2560 | 970 | 1120 |

HJA-6 Clear-cut summer 1974
HJA-7 Shelterwood cut (60% of BA removed) summer 1974
Analysis using regressions with control HJA-8.

At HJA-6, streamflow increase in the first year after logging was 420 mm and averaged 380 mm in the first 4 yr; HJA-7 averaged an increase of 200 mm in the first 4 yr after logging.

Low flow days = days with mean streamflow less than 0.022 L/s/ha. Now have fewer low flow days than predicted by regression analysis.

Storm flows:
Could not detect a change in peak flows greater that 4.5 L/s/ha nor in the timing of the peaks.

**Changes in timing storm peaks after logging**

| | Pre-logging | | Post-logging | | |
|---|---|---|---|---|---|
| | No. of peaks | Time difference (hours) | No. of peaks | Time difference (hours) | t |
| HJA-6 | 17 | 3.6 | 8 | 4.2 | −0.371 |
| HJA-7 | 16 | -0.6 | 7 | 3.1 | −1.53 |

**Harr, R.D.; McCorison, F.M. 1979: Initial effects of clear logging on size and timing of peak flows in a small watershed in Western Oregon. Water Resources Research 15: 90–94.**

| | |
|---|---|
| Country: United States | Report Location: LKR |
| Land-Use Change: Harvesting | |
| Stand Type: Old-growth forest and up to 10–15-yr-old regrowth | |
| Keywords: Storm flow | |

*Comment*
The paper reports first year after logging events. The data implied reductions in storm peaks and increases in time to peaks. The data have been reviewed and updated by Harr (1986) with differing conclusions.

**Harris, D.D. 1973: Hydrologic changes after clearcut logging in a small Oregon coastal watersheds. Journal of Research of the US Geological Survey 1:487–491.**

| | | |
|---|---|---|
| Country: United States | Duration: 11 yr | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: Mixed forest with Douglas fir; − 7 to + 4 yr | | Rainfall: MAP 2400 mm |
| Keywords: Low flow; Storm flow; Water quality; Water yield | | |

*Comment*
Alsea Watershed Study, Oregon. Needle Branch clear-cut.
Lists annual streamflow for the 11 yr and implies an increase in streamflow of over 20 inches (500 mm).

Peak flows over =50 cfs/miles$^2$ (= 547 L/s/km$^2$) may have shown an increase but it was not statistically significant — small sample size the reason??

Low flows — used September (= Southern Hemisphere March) minimum — results as for peak flows.

**Harris, D.D. 1977: Hydrologic changes after logging in two small Oregon coastal watersheds. US Geological Survey Water-supply Paper 2037. 31 p.**

| Country: United States | Duration: 15 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Mixed forest with Douglas fir; −7 to + 7 yr | | Rainfall: MAP 2400 mm |
| Keywords: Low flow; Storm flow; Water quality; Water yield | | |

*Comment*
Alsea Watershed Study, Oregon. Updates Harris (1973) and includes Deer Creek.

**Changes after harvesting at Alsea**

| | Deer Creek | Needle Branch |
|---|---|---|
| Annual runoff (mm (%)) | 64 (3) | 480 (26) |
| Peak flow (L/s/ha (%)) | 0.2 (2) | 1.95 (20) |
| Low flow (L/s/ha (%)) | − 0.006 | 0 |

This paper does not indicate the degree of harvesting. From Harr et al. (1975) it appears that Deer Creek was 29% harvested and Needle Creek was 86% harvested.

Gives a table of annual yields for the two treated catchments and Flynn Creek, the control catchment. No rainfall data for the post-harvest period.

**Helvey, J.D. 1972: First-year effects of wildfire on water yield and stream temperature. *In*: Csallany, S.C.; McLaughlin, T.G.; Striffler, W.D. *ed.* Watersheds in Transitions. American Water Resources Association. Urbana, Ill. Pp. 308–312.**

| Country: United States | Report Location: R1467 |
|---|---|
| Land-Use Change: Fire | |
| Stand Type: Mature mixed forest with Douglas fir | |
| Keywords: Water yield | |

*Comment*
Entiat Experimental Forest, Washington.

Three catchments were virtually 100% burned. First year increases in streamflow over that predicted were 94, 104 and 69 mm.

**Helvey, J.D.; Tiedemann, A.R. 1978: Effects of defoliation by Douglas-fir tussock moth on timing and quantity of streamflow. United States Department of Agriculture Forest Service, Pacific Northwest Forest and Range Experiment Station Research Note PNW-326. 13 p.**

| | | |
|---|---|---|
| Country: United States | Duration: 2 yr | Report Location: Not sighted |
| Land-Use Change: Insect damage | | |
| Stand Type: Old-growth forest | | |
| Keywords: Water yield | | |

*CAB Abstracts AN 800573273*

Streamflow data from three watersheds in the Blue Mountains of Oregon were analysed for changes in annual runoff, summer runoff and peak discharge following defoliation by *Orgyia pseudotsugata* (McDunn.) in 1972 and 1973. Annual runoff from the Umatilla River watershed in 1974 was 13.2 cm greater than the predicted value and 2.5 cm greater than the end-point 95% confidence band for the baseline data. No changes in runoff were detected on the North or South Fork of the Walla Walla River. Defoliation was more extensive on the Umatilla drainage.

*Comment*

Included for interest — the effect would be similar to pruning. Extent of defoliation not stated in the abstract.

**Henderson, G.S.; Swank, W.T.; Waide, J.B.; Grier, C.C. 1978: Nutrient budgets of Appalachian and Cascade region watersheds: a comparison. Forest-Science 24: 385–397.**

| | | |
|---|---|---|
| Country: United States | Duration: 2 yr | Report Location: R420 |
| Stand Type: 450-yr old-growth forest with 60–80-m high Douglas fir | | |
| Keywords: Nutrient cycling; Water yield | | |

*CAB Abstracts AN 780649680*

Precipitation inputs and streamflow outputs of N, Ca, K, Mg and Na were compared for three watersheds: Andrews Watershed 10 (alt. 430–670 m) in Oregon, dominant vegetation Douglas fir (upper slopes) with *Tsuga heterophylla* (middle and lower slopes); Coweeta Watershed 18 (alt. 721–1006 m) in North Carolina, dominated by *Quercus* spp. with *Carya* spp. and *Acer rubrum;* Walker Branch Watershed (alt. 265–360 m) in eastern Tennessee, dominated by *Quercus* and *Carya* spp. with small numbers of *Pinus virginiana*, *P. echinata*, and *Liriodendron tulipifera*. Inputs of N varied by nearly 10-fold, but NH4-N and NO3-N output was small, giving a net accumulation. Cation output was more variable than input and related to bedrock of the watershed. Data are also tabulated for biomass distribution in vegetation and forest floor; and distribution, cycling and losses of N, K, and Ca. Comparisons of losses with compartment sizes and annual transfers shows that all three ecosystems were effectively retaining and recycling these nutrients; differences in cycling patterns between coniferous and broadleaved forests are discussed.

*Comment*

Only Watershed 10 at H J Andrews Experimental Forest, Oregon, is considered here — the others are on the east coast and do not have Douglas fir.

Precipitation 2330 mm; Streamflow 1530 mm. 2 yr of data.

**Heuveldop, J.; Mitscherlich, G.; Kunstle, E. 1972: Throughfall, stemflow and interception loss in Douglas fir stands on south and north slopes. Allgemeine Forst und Jagdzeitung 143: 117–121.**

| | | |
|---|---|---|
| Country: Germany | Duration: Two summers | Report Location: LKR |
| Stand Type: Plantation 31 & 45 yr | Stand Density: 932 & 760 SPH | Basal Area: 36.4 & 41.4 $m^2$/ha |
| Height: 24 & 23.4 m | Diameter: 22.3 & 26.3 cm | |
| Keywords: Interception; Stemflow; Throughfall | | |

*CAB Abstracts AN: 720601117*

In order to check whether interception values of 30–41% found on a steep southern slope in an earlier study [cf. FA 31, 5808] were representative for Douglas fir stands aged 13–40 yr, similar measurements were made in 1970 and 1971 (a) in a 41-yr-old stand on a southern slope and (b) in a near-by 35-yr-old stand on a gentle northern slope, both in Freiburg district, Schwarzwald. In 1970, a year of above-average precipitation, precipitation above the canopy was less for (a) than for (b); in 1971, a rather dry year, there was little difference between the two sites. Throughfall in (b) was 66% in both years; in (a) it was 72% in 1970 and only 55% in 1971. Stemflow was only 4% in (a) in both years, and 3 and 2% in (b) in 1970 and 1971 respectively. Wind is thought to be one of the factors affecting interception differently in different conditions. It is suggested that in warm, rather dry years, stands exposed to wind dry quickly, so that interception losses become higher, while in cool, wet years, more water is shaken from the crowns of the trees, so that interception becomes less.

*Comment*

An update on Mitscherlich & Moll (1970)

**Rainfall interception (mm and %) by Douglas fir on north and south slopes**

| | South | | | | North | | | |
|---|---|---|---|---|---|---|---|---|
| Year | PTTN | TF | SF | INTN | PTTN | TF | SF | INTN |
| 29-6-70 to 2-11-70 | 270 | 195 (72) | 12 (4) | 63 (24) | 355 | 234 (66) | 11 (3) | 111 (31) |
| 3-5-71 to 2-11-71 | 436 | 259 (59) | 14 (3) | 163 (37) | 471 | 313 (66) | 8 (2) | 150 (32) |

Combining the two years gave the same percentage interception losses for both slopes.

**Hicks, B.J.; Beschta, R.L.; Harr, R.D. 1991: Long-term changes in streamflow following logging in western Oregon and associated fisheries implications. Water Resources Bulletin 27: 217–226.**

| Country: United States | Duration: 36 yr | Report Location: LKR |
|---|---|---|
| Landuse change: Harvesting | | |
| Stand Type: Old-growth forest – 9 to 25 yr | | |
| Keywords: Low flow; Water yield | | |

*Comment*
HJ Andrews Catchments: WS-1 clear-felled over 5 yr then burned; WS-2 uncut control; WS-3 25% patch-cut and patches burned in 1 yr.
WS-1: Increased water yield, up to 520 mm/yr. Over the 8 yr after burning this dropped to about 250 mm above preharvest levels where it stayed for the next 14 yr.
WS-3: Increased water yield, up to 200 mm/yr. Over the 11 yr after treatment the increase averaged about 100 mm/yr above preharvest levels and has stayed about 50 mm higher over the next 14 yr.

There are obvious wet and dry year effects superimposed over these trends but no rainfall data to look at these in detail.

August streamflows are the lowest for the year and at WS-1 these are elevated above pretreatment levels by up to 11 mm and average 5 mm higher until 3 yr after burning when they drop to about 1 mm lower than before harvesting. At WS-3, August streamflows have generally remained higher than pretreatment levels, the increase being sustained 9 yr longer than for WS-1.

**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 |
|---|---|---|
| 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 [TF] 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%)

**Houdijk, A.L.F.M.; Roelofs, J.G.M. 1991: Deposition of acidifying and eutrophicating substances in Dutch forests. Acta Botanica Neerlandica 40: 245–255.**

| Country: The Netherlands | Duration: 18 months | Report Location: LKR |
|---|---|---|
| Species Comparison: Pine species | | |
| Stand Type: Plantation vary between 25 and 40 yr | | |
| Keywords: Throughfall | | |

*CAB Abstracts AN 930673252*

In order to identify and quantify the acidifying and eutrophying substances that contribute to atmospheric deposition in Dutch coniferous forests (*Pinus nigra* var. *maritima*, *P. sylvestris*, Douglas fir), open field precipitation and throughfall water were sampled monthly at 14 locations in The Netherlands over an 18-month period. Spatial variation was studied by comparing chemical composition of deposition in forests of four regions. Within forests, throughfall fluxes of different tree species were compared. In this paper, deposition fluxes of sulphuric and nitrogenous compounds are emphasised. Most forested areas in The Netherlands received high annual loads of nitrogenous (5.6 kmol N/ha) and potentially acidifying (9.4 kmol H/ha) compounds. Particularly, deposition of ammonium and sulphate was high, not only in areas with intensive agricultural activities, but throughout the country. Regional differences in deposition appeared to be relatively small. With the exception of the two coastal locations, deposition showed little spatial variation. In the coastal region loads of nitrogenous and potentially acidifying compounds were lower than elsewhere in the country. Generally higher throughfall fluxes were measured in Douglas fir stands than in pine stands. The larger surface area of Douglas fir probably accounts for enhanced dry deposition. In summer, throughfall fluxes were generally smaller than in winter.

*Comment*

This table is a summary as presented with percentages added by LKR. It's based on 14 locations.

**Throughfall (mm and %) for various stands**

| Region | PTTN | Douglas fir | Corsican pine | Scots pine |
|---|---|---|---|---|
| Coastal | 812 | – | 627 (77) | 539 (66) |
| Northern | 1037 | 674 (65) | 779 (73) | 695 (67) |
| Central | 1125 | 550 (49) | 710 (63) | 753 (67) |
| Southern | 1044 | 669 (64) | 511 (49) | 719 (69) |

**Ingwersen, J.B. 1985: Fog drip, water yield and timber harvesting in the Bull Run municipal watershed, Oregon. Water Resources Bulletin 21: 469–473.**

| Country: United States | Duration: | Report Location: R918 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Old-growth forest | | |
| Keywords: Fog; Water yield | | |

*Authors' Abstracts*

Analysis of recent streamflow data from the Fox Creek Experimental Watersheds in the Bull Run Municipal Watershed, Oregon, indicates a significant recovery from the impacts on summer water yield due to a loss of fog drip upon timber harvesting. Measurable impacts and their associated recovery are only notable during the months of June and July. Recovery begins about 5 or 6 yr following harvest, possibly due to renewed fog drip from prolific revegetation. Watershed positioning with respect to prevailing weather systems and the extent of burning or removal of slash and residual vegetation during logging appear to be important factors in predicting the impact of fog drip reduction associated with planned harvest. Apparently, once the temporary reduction in summer yield is offset by renewed fog drip, the expected increase in yield due to decreased evapotranspiration can be observed. Redistribution of fog drip may be a major factor in the measurement of local interception and water yield.

*Comment*

An unusual case not likely to be found in New Zealand but listed for completeness.

**Jones, J.A. 2000: Hydrologic processes and peak discharge response to forest removal, regrowth, and roads in 10 small experimental basins, western Cascades, Oregon. Water Resources Research 36: 2621–2642.**

| Country: United States | Report Location: LKR |
|---|---|
| Land-Use Change: Forest management; Harvesting | |
| Stand Type: Natural forest | |
| Keywords: Storm flow | |

*Comment*

This paper is one of a number of papers (Jones & Grant 1996; Thomas & Megahan 1998; and published comments) debating the responses of catchment peak flows to forest management. Four 100% clear-cut catchments, two 50% clear-cut, and four 25–30% patch-cut. Most of these were dominated by mature to old-growth Douglas fir.

Various event classes were used: season, small, large, rain only, rain-on-snow, etc. Roading, harvesting, and regrowth effects were looked for. Generally looked at pretreatment, and decadal post-treatment data. Because of the wide-ranging study, see the paper for detailed results. In general, there were significant increases of varying magnitudes after harvesting, and after roading, but not in all catchments.

**Jones, J.A.; Grant, G.E. 1996: Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resources Research 32: 959–974.**

| | |
|---|---|
| Country: United States | Report Location: R152 |
| Land-Use Change: Forest management; Harvesting | |
| Stand Type: Natural forest | Stand Density: various |
| Keywords: Storm flow | |

*Comment*
This paper is one of a number of papers (Thomas & Megahan 1998, Jones 2000; and published comments) debating the responses of catchment peak flows t o forest management.

Three small catchments at HJ Andrews + six larger catchments.

‘Forest harvesting increased peak discharges by as much as 50% in small basins and 100% in large basins over the past 50 years. These increases are attributable to changes both in flow routing due to roads and in water balance due to treatment effects and vegetation sucession.’

**Kelliher, F.M.; Black, T.A.; Price, D.T. 1986: Estimating the effects of understory removal from a Douglas fir forest using a two-layer canopy evapotranspiration model. Water Resources Research 22: 1891–1899.**

| | | |
|---|---|---|
| Country: Canada | Duration: | Report Location: R149. |
| Land-Use Change: Forest management | | |
| Stand Type: 32 yr | Stand Density: 800 SPH | Basal Area: 16 $m^2$/ha |
| Height: 14 m | | |
| Keywords: Evaporation; Model | | |

*CAB Abstracts AN 871911989/Authors’ Abstract*

W.J. Shuttleworth's (1979) development of the Penman-Monteith evaporation equation for multilayer, partially wet forest canopies was modified for application to the hypostomatous canopies of Douglas fir and salal [*Gaultheria shallon*]. This theory was combined with standard hourly micrometeorological measurements, eddy diffusive, boundary layer and stomatal resistance functions, and canopy and root-zone water balance equations to calculate evapotranspiration rates (E) from a Douglas fir forest with salal understorey over extended periods during two growing seasons. Calculated values of E agreed to within 0.2 mm/day of values determined using Bowen ratio-energy balance measurements. The courses of average root zone volumetric water content (theta) calculated for two extended periods agreed well with neutron probe measurements. Salal understorey removal resulted in measured values of theta being only 0.01–0.03 $m^3/m^3$ higher over the two periods, in close agreement with calculations. This corresponded to calculated tree transpiration rates being 0.4 mm/day higher on average, during the second half of both periods. These higher rates were confirmed by stomatal resistance measurements.

**Keppeler, E.T. 1998: The summer flow and water yield response to timber harvest. *In*: Ziemer, R.R. (Technical Coordinator) Proceedings of the conference on coastal watersheds: The Caspar Creek story. USDA Forest Service General Technical Report PSW-GTR-168: 35–43.**

| Country: United States | Duration:35 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Second growth with redwoods | | |
| Keywords: Low flow; Water yield | | |

*Comment*
A continuation of the Caspar Creek story.

After South Fork was selection cut, water yields increased by a maximum of 205 mm in the 7th year after harvesting. Increased yields were observed from the 2nd year after harvesting and averaged 93 mm/yr. North Fork was 50% logged and there was a yield increase of 103 mm by the 8th year after logging with an average increase of 15% or 61 mm beginning the 2nd year after logging.

At South Creek there were increased summer yields for 7 yr after logging after which they fell to pretreatment levels. Summer flow increase amounted to minor increases in minimum discharges averaging 0.0025 L/s/ha at South Fork and 0.004 L/s/ha at North Fork but these were 38% and 148% higher than pretreatment levels.

**Keppeler, E.T.; Ziemer, R.R. 1990: Logging effects on streamflow: water yield and summer low flows at Caspar Creek in Northwestern California. Water Resources Research 26: 1669–1679.**

| Country: United States | Duration: 21 yr | Report Location: R146 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Second growth | | Rainfall: MAP 1200 mm |
| Keywords: Low flow; Water yield | | |

*CAB Abstracts AN 940600293/Authors' Abstract*

Streamflow data for a 21-year period were analysed to determine the effects of selective tractor harvesting of second-growth Douglas fir and redwood forest on the volume, timing, and duration of low flows and annual water yield in north-western California. The flow response to logging was highly variable. Some of this variability was correlated with antecedent precipitation conditions. Statistically significant increases in streamflow were detected for both the annual period and the low-flow season. Relative increases in water yield were greater for the summer low-flow period than for annual flows, but these summer flow increases generally disappeared within 5 yr.

*Comment*
Catchments studies were North and South Forks of Caspar Creek. 67% of the vegetation was removed from South Fork.

A low-flow season was defined by an antecedent precipitation index $API_i = K \times API_{i-1} + P_i$ where

$P_i$ = precipitation on day i, $K^+$ is a recession constant <= 1 (used 0.97). The season was defined as the period when the API fell below and exceeded a value of 100 mm. The start dates corresponded with a flow of about 0.58 L/s/ha.

Flow increases 54 (7%) to 233 (34%) mm in the 9 yr after harvesting; low flows increased 14 to 55%. The number of low flow days, flow < 0.16 L/s/ha, decreased 40% (43 days) over 5 yr and returned to normal after that.
Performed multiple regression analyses on a range of flow and precipitation variables.

**Kitching, R. 1967: Water use by tree plantations. Journal of Hydrology 5: 206–213**

| Country: England | Duration: 8 months | Report Location: LKR |
|---|---|---|
| Species Comparison: Pine species | | |
| Stand Type: Plantation | | |
| Keywords: Evaporation | | |

*CAB Abstracts AN 2901783*

Water balances in six plantations in England were investigated: (a) Douglas fir and (b) Corsican Pine at Bramshill, Hants., and at Rendlesham, Suffolk; and (c) Sitka spruce and (d) a Coriscan-pine/Scotspine mixture at Burley, Hants. Soil moisture was assessed by the neutron-probe technique and percolation was estimated during the early winter (to minimise absolute errors in estimates of evaporation). The mean value for the ratio of evaporation of pines to that from open water was 0.7 +-0.25; the highest value recorded was 0.81 +-F 0.23 in (d), and the lowest 0.49 + 0.18 in (c).

*Comment*

This comment only compares Douglas fir with Corsican pine at the same localities. No stand information given. Evaporation from the two species was similar in winter at the same locality but there were conflicting comparisons in summer.

| | Locality | Species | Days | PTTN (mm) | Change in SM (mm) | Estimated E (mm) | Rate (mm/day) |
|---|---|---|---|---|---|---|---|
| Autumn | Bramshill | Douglas fir | 57 | 721 | 18 | 22 | 0.4 |
| | Bramshill | Corsican pine | 118 | 214 | 89 | 35 | 0.3 |
| | Rendlesham | Douglas fir | 43 | 50 | − 18 | 31 | 0.7 |
| | Rendlesham | Corsican pine | 43 | 50 | − 15 | 31 | 0.7 |
| Summer | Bramshill | Douglas fir | 144 | 304 | − 12 | 245 | 1.7 |
| | Bramshill | Corsican pine | 141 | 311 | − 19 | 215 | 1.5 |
| | Rendlesham | Douglas fir | 128 | 281 | 0 | 173 | 1.4 |
| | Rendlesham | Corsican pine | 128 | 281 | − 43 | 226 | 1.8 |

**Kline, J.R.; Reed, K.L.; Waring, R.H.; Stewart, M.L. 1976: Field measurement of trans-piration in Douglas-fir. Journal of Applied Ecology 13: 273–283.**

| Country: United States | Duration: 1 month | Report Location: LKR |
|---|---|---|
| Stand Type: Natural forest | | |
| Keywords: Transpiration | | |

*CAB Abstracts AN 761926670*

Transpiration rates of Douglas-fir trees were measured in the field, using tritiated water (HTO) as a tracer for water. Sites were located in the Cedar River watershed near Seattle, Washington and in the Andrews Experimental Forest near Eugene, Oregon. Transpiration rates ranged from 8.4 L/day in a small tree to 530 l/day in a large old-growth tree on the Oregon site. A relationship between transpiration rate and sapwood cross-sectional area of trees was found that would permit extension of individual tree measurements to forest populations. The HTO measurements, linked to current physical theories of evapotranspiration, permit the computation of actual daily transpiration rates for individual trees or areas of forest. The method allows direct measurements of water loss from forests in situations where lysimeter installation would be impractical.

*Comment*

Did not upscale from the tree to forest basis.

**Kreutzer, K.; Beier, C.; Bredemeier, M.; Blanck, K.; Cummins, T.; Farrell, E.P.; Lammersdorf, N.; Rasmussen, L.; Rothe, A.; de Visser, P.H.B.; Weis, W.; Weib,T.; Xu, Y.J. 1998: Atmospheric deposition and soil acidification in five coniferous forest ecosystems: a comparison of the control plots of the EXMAN sites. Forest Ecology and Management 101: 125–142.**

| Country: The Netherlands | Duration:2 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Plantation | | |
| Keywords: Throughfall | | |

*CAB Abstracts AN: 980607478*

The five sites of the EXMAN project in Ireland, Denmark, The Netherlands, and northern and southern Germany (all *Picea abies* plantations except for the Dutch site which is a Douglas fir plantation) were compared regarding (a) the marine and anthropogenic components of deposition, (b) the acidification of soil and consequences for Al status, and (c) the nitrate load of seepage. The marine deposition decreases with decreasing rates from the coast inland. It vanishes at a distance of more than 600 km from the sea. The major part of sea salt input the conifer plantations is due to dry deposition. Sea salt Mg2+ in throughfall near the coast by far exceeds the demand of trees. The anthropogenic deposition of N and S at the Irish site is about 20%, and at the Danish site about 60% of that at the inland sites. At the Irish site, the anthropogenic deposition is 2–3 times that of the preindustrial deposition. NH+4 prevails at all sites as the acid component in throughfall, controlling the pH values that vary between 3.9 and 5.3. In drainage water leaving the root zone, the mean pH values vary only between 4.1 and 4.4. Proton budgets for the forest floor have shown that N turnover dominates as a proton source at the inland sites, whereas at the coastal sites the dominant source results from the production of organic acids. The main proton sink is due to H+ output. Proton budgets for the total root zone indicate that an important proton gain is caused at most sites by proton excretion of the roots in connection with base cation uptake. In addition, at some sites, the release and output of SO2-4 appears to be a considerable proton source. At all sites, buffering and output of Al represent the main proton sink. The Al solubility of each layer of the EXMAN sites was compared with the solubility of a synthetic gibbsite. Al saturation exists only at the lower boundary of the main root zone. In the soil layers above, there is an undersaturation that is largest at the humus layer efflux. The relationship between Al dissolved and Al adsorbed, both expressed in cation percentages, is rather weak for the coastal sites in contrast to the inland sites. The importance of the ionic strength effect of sea salt input is discussed with respect to the deep reaching Al saturation and acidification of the soils. Moderate to strong Al stress is indicated at all sites in the mineral soil. The nitrate load of the seepage water depends on the N status of the ecosystems rather than on N deposition when the throughfall exceeds 20 kg N ha/yr. An attempt was made to classify the EXMAN sites with respect to the N status with the aid of the N flux gradient by depth.

*Comment*
EXMAN project, Kootwijk site in The Netherlands. Does give information for other species in other countries. Not given here as precipitation regimes will be different. See Farrell et al. (1994) for details of the stands.

Three-year mean annual PTTN 776 mm; Throughfall 469 mm (=60%)
Stemflow does not appear to have been measured.

**Krygier, J.T. 1971: Comparative water loss of Douglas-Fir and Oregon White Oak. Water Resources Institute, Oregon State University, Project completion report, W71-11063, OWRR-001- REG(9).**

| | |
|---|---|
| Country: United States | Report Location: Not sighted |
| Species comparison: Native deciduous forest | |
| Keywords: Interception | |

*CAB Abstracts AN: 730610312*

A water budget was determined for pure, fully stocked stands of (a) Douglas fir and (b) *Quercus garryana* from measurements of gross precipitation in openings, throughfall, and soil-water changes. Potential water loss was measured on plots irrigated for one summer, and plastic barriers were installed under the canopy and in the soil for 1 yr to permit early spring and winter measurements. Interception storage was 0.13 inches (in winter) and 0.20 inches (in summer) for (a), and 0.02 inches (leafless) and 0.10 inches (in leaf) for (b). Mean interception losses 1965 and 1966 were 8 inches (21%) for (a), and 3 inches (7.5%) for (b). Computed hydraulic gradients indicated downward movement in the soil profile under (b) for a longer period in the spring.

**Kunstle, E.; Mitscherlich, G. 1977: Photosynthesis, transpiration and respiration in a mixed stand in the Black Forest. IV. Balance. (Photosynthese, Transpiration und Atmung in einem Mischbestand im Schwarzwald. IV. Teil: Bilanz.) Allgemeine Forst und Jagdzeitung 148: 227–239.**

| Country: Germany | Report Location: Not sighted |
|---|---|
| Species comparison: Native deciduous forest; Pine species | |
| Keywords: Evaporation; Interception | |

*CAB Abstracts AN: 780643221*

[See FA 38, 1727] Net photosynthesis was calculated for light and shaded crowns of Douglas fir, pine [*Pinus sylvestris*], beech [*Fagus sylvatica*] and birch [*Betula* spp.]. For Douglas fir and pine, account was taken of needle age. Corrections for azimuth were made as the gas exchange chambers were on the south side of the crowns. Production per tree was estimated from 9–10 felled sample trees for each species. Leaf mass and branch and stem surface area were measured for light and shaded crowns. Respiration per diameter squared was estimated for stems and branches. These values were used to calculate total biomass production per hectare and stem and branch biomass production. Results corresponded closely with those obtained by different methods in other stands. Annual transpiration rates were estimated for Douglas fir and pine and the water balance was calculated from data on precipitation and interception and assessed values of soil evaporation. The results indicated a low rate of infiltration (181–263 mm) in young, vigorously growing stands on a sunny southern slope.

**Langford, K.J.; O'Shaughnessy, P.J. (Editors) 1977: A study of canopy interception in native forests and conifer plantations. Melbourne and Metropolitan Board of Works, Victoria Report No. MMBW-W-0007.**

| Country: Australia | Duration: 8 yr | Report Location: Landcare Library |
|---|---|---|
| Species Comparison: Conifers; Eucalypts; *Pinus radiata*; Scrubland | | |
| Stand Type: Plantation 40–48 yr | Stand Density: 668 SPH | Basal Area: 55 $m^2$/ha |
| Height: 30.2 m | | |
| Keywords: Interception; Stemflow; Throughfall | | |

*CAB Abstracts AN F255876*

In Victoria, Australia, no significant differences in interception were found between old-growth *Eucalyptus regnans*, mixed eucalypt forest and *Pinus radiata*. Interception of 1939 regrowth *E. regnans* was lower than that of mature *E. regnans*. Interception of *Pomaderris aspera* was significantly lower while those of *Sequoia sempervirens* and Douglas fir were significantly higher than that of mature *E. regnans*.

*Comment*

Same stands as for Duncan et al. (1978).

375 observations for TF: Data collection weekly and the last day of the month from early 1970 to May 1978.

$TF = PTTN \times 0.604 - 0.72$
$SF = PTTN \times 0.161 - 0.60$
$IL = PTTN \times 0.235 + 1.32$

**Interception results from Victoria**

| | Throughfall (%) | Stemflow (%) | Interception loss (%) |
|---|---|---|---|
| Mixed species | 75.4 | 1.3 | 23.3 |
| Hazel | 73.2 | 12 | 14.8 |
| Mature ash | 72.5 | 4.3 | 23.2 |
| Regrowth ash | 76 | 5.3 | 18.7 |
| Musk | 75.1 | | |
| Redwood | 59.8 | 1.1 | 39.1 |
| *P. radiata* | 68 | 10.6 | 21.4 |
| Douglas fir | 58 | 14.1 | 27.9 |

**Leaf, C.F. 1975: Watershed management in the Rocky Mountain subalpine zone: the status of our knowledge. USDA Forest Service Research Paper, Rocky Mountain Forest and Range Experiment Station RM-137. 31 p.**

| | |
|---|---|
| Country: United States | Report Location: Not sighted |
| Land-Use Change: Forest management | |
| Stand Type: Natural forest | |
| Keywords: Review | |

*CAB Abstracts AN: 750625814*

Describes the management of catchments in the subalpine zone of Wyoming, Colorado and New Mexico (a zone characterised by stands of *Pinus contorta*, *Picea engelmannii/Abies lasiocarpa*, Douglas fir and *Populus tremuloides*), and considers the forest hydrology of the area in detail. In particular the author reviews and discusses (a) field studies on the effects of different catchment management practices on the accumulation and melting of snow, and on subsequent runoff, and (b) simulation models for predicting the hydrological effects of logging and modification of the weather. Relevant literature is reviewed, requirements for further research are emphasised, and recommendations are made for applying principles of catchment management in land-use planning.

*Comment*
Not sighted

**Martin, I.L.; Tinney, E.R. 1962: Logging in West Coast watershed shows no effect on area's water yield. Timberman 63: 46–48.**

| Country: United States | Report Location: Not sighted |
|---|---|
| Land-Use Change: Harvesting | |
| Stand Type: Natural forest | |
| Keywords: Water yield | |

*CAB Abstracts AN: 2401537*

Presents data on areas logged (1916–54), annual precipitation (130 in.) and runoff, and on the 19 classes of cover in hemlock/Douglas fir forest of the 55-sq. mile basin of the Naselle River, Wash., to show that conservative logging had a negligible influence on water yield and base flow. These results are ascribed to the heavy rainfall, moderate climate and good soils, permitting rapid regrowth, and to the small areas annually logged-averaging 702 acres or <2% of the whole.

*Comment*
Not sighted — not in New Zealand.

**McNaughton, K.G.; Black, T.A. 1973: A study of evapotranspiration from a Douglas fir forest using the energy balance approach. Water Resources Research 9: 579–590.**

| Country: Canada | Duration: 18 days—July | Report Location: LKR |
|---|---|---|
| Stand Type: Plantation — young 7.8 m high | | |
| Keywords: Evaporation | | |

*CAB Abstracts AN: 740616728*

Energy-balance measurements of evapotranspiration are reported for a young plantation of Douglas fir (ca. 7.8 m high) in British Columbia, for an 18-day period in July 1970 when soil moisture was not limiting. Peak daily evapotranspiration rates characteristically occurred 2–3 hours after solar noon, and evapotranspiration showed a short-term independence from net radiation. This behaviour is interpreted as being a consequence of the canopy roughness. Daily evapotranspiration and net radiation were, however, well correlated. Values of surface diffusion resistance calculated from Monteith's combination formula are presented; there were large day-to-day differences in daytime values. Comparison of evapotranspiration measurements with a potential evaporation formula for wet surfaces developed by Priestley and Taylor suggest that evaporation of intercepted moisture proceeds 20% more rapidly than does evapotranspiration from an unwetted canopy.

*Comment*
Eavporation ranged between 1.46 and 4.80 mm/day.

**Mitscherlich, G.; Moll, W.; Kunstle, E.; Maurer, P. 1966: Research on ecology and yield in pure and mixed stands. Part IV: Precipitation, stemflow and soil moisture. (Ertragskundlich-okologische untersuchungen im rein-und mischbestand. Part IV: Niederschlag, stammablauf und bodenfeuchtogkeit) Allgemeine Forst- und Jagdzeitung 137: 1–13.**

| Country: Germany | Duration: 3 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Thinned plantations | | |
| Keywords: Interception; Stemflow | | |

*CAB Abstracts* AN: 2705700

This paper is in seven parts: (1) Situation, soil and stand characteristics; (2) Wind, total radiation and light within the stand; (3) Temperature; (4) Precipitation, stem-flow and soil moisture; (5) Relative humidity, evaporation and $CO_2$ content of the air; (6) Onset and termination of [radial] growth, diameter variations, and annual diameter growth; and (7) Height growth and increment per hectare. It discusses the first two years' results of a research project on microclimate and growth in two Douglas fir stands, aged ca. 35 yr, near Freiburg [cf. F.A. 27 No. 3921], and in a mixed stand, typical for the site, of 80-yr-old pine with an understorey of oak and beech. There were only minor differences in air and soil temperatures and r.h. between the two thinning regimes of Douglas fir, greater differences in relative illumination, wind and evaporation, and considerable differences in interception and stemflow. Differences between the Douglas fir stands and the mixed stand were much greater. There was much less interception in the latter, but soil moisture in the three stands differed only slightly. In Douglas fir, diameter and height development, studied in some detail, appeared to be related to temperature in May, and to precipitation later. Current volume increment in Douglas fir was about twice that of the mixed stand, and m.a.i. was also nearly twice as great.

*Comment*

Presents a review table of pre-1965 interception and stemflow data (as percentages) for *P. sylvestris*, *Fagus* spp., *Abies pectinata*, *Picea abies*, *Tsuga heterophylla*, and Douglas fir.

Stemflow was 5.6% in the heavily thinned stand and 8.7% in the lightly thinned stand.
Interception loss was 35% in the heavily thinned stand and 41% in the lightly thinned stand.

**Mitscherlich, G.; Moll, W. 1970: Studies on precipitation and soil moisture in some conifer and hardwood stands near Freiburg-i. Br. Part I. Precipitation. (Untersuchungen uber die niederschlags und bodenfeuchtigkeitsverhaltnisse in einigen nadel and laubholzbestanden in der nahe von Freiburg/Br. Teil I: Niederschlagsverhaltnisse.). Allgemeine Forst. und Jagdzeitung. 141: 49–60.**

| Country: Germany | Duration: 5 yr | Report Location: LKR |
|---|---|---|
| Species comparisons: Native deciduous forest; Pine species | | |
| Stand Type: Plantations — various | | |
| Keywords: Interception; Stemflow; Throughfall | | |

*CAB Abstracts AN: 3105808*

A 4-yr study of throughfall and stemflow in eight Douglas fir stands aged 5 to 40 yr, unthinned and variously thinned, a 40-yr beech stand, and a Scots pine stand with beech/oak understorey [cf. F.A. 27 No. 5700]. Results are shown in tables and graphs. Excluding a 5-yr stand, interception in Douglas fir varied from 30 to 41%; in the beech it was 24%; and in the mixed stand 30%.

*Comment*
Throughfall was greater in summer than winter. Thinning may have increased throughfall by 5–10%. Stemflow ranged between 4 and 10% of rainfall for the Douglas fir stands, was 13% for the beech stand and 3% for the Scots pine stand.

**Nnyamah, J.U.; Black, T.A. 1977: Rates and patterns of water uptake in a Douglas fir forest. Soil Science Society of America Journal 41: 972–979.**

| Country: Canada | Duration: Two summers | Report Location: R150 |
|---|---|---|
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 20 yr | Stand Density: See below | |
| Keywords: Evaporation | | |

*CAB Abstracts AN 780651731*
A study in (a) thinned stands (840 stems/ha) and (b) unthinned stands (1840 stems/ha) of 20-yr-old Douglas fir in British Columbia during the summer of 1974 and 1975. Data are presented showing: soil physical and hydrological properties; root biomass, soil moisture tension, volumetric water content and water flux, and distribution of water uptake by roots, at different depths, during a 4-week drying period; and derived values for root-zone depletion and net movement of water, and evapotranspiration. The zone of maximum water uptake moved gradually downward as the soil dried. Water flux at the bottom of the root zone changed from downward to upward during July, but amounts were small and never more than 15% of the evapotranspiration rate. Evapotranspiration estimates by the water balance and Bowen micrometeorological energy balance methods were similar. Water withdrawal from stem storage accounted for only 2% of total evapotranspiration in (a) during the drying period.

*Comment*

**Daily evapotranspiration (mm)**

| 1974 Period | Thinned stand | 1975 Period | Unthinned stand |
|---|---|---|---|
| 18–22 July | 2.8 | 1–6 July | 3.6 |
| 11–28 July | 2.3 | 6–11 July | 3.4 |
| 28 July – 4 Aug | 2.5 | 11–18 July | 2 |
| 4–11 Aug | 1.9 | 18–25 July | 1.9 |
| 11–17 Aug | 1 | 25 July – 1 Aug | 1.2 |

**Rao, S.V.N. 1998: Modeling the effect of partial forest cutting on stream flow. Van Vigyan 36: 95–104.**

| Country: United States | Report Location: Not sighted |
|---|---|
| Land-Use Change: Harvesting | |

| Stand Type: Natural forest |
|---|
| Keywords: Stormflow; Water yield |

*CAB Abstracts AN: 20000606618*

Forest hydrology studies often use two or more similar watersheds, with one of them serving as a control, to evaluate the effects of various practices on streamflow. Data from two small forested watersheds that were partially harvested (helicopter logged) and an undisturbed control watershed were used in this study; the data available for pre- and post-felling periods varied in the two case studies. The watersheds are located in the Silver Creek study area in SW Idaho, United States, and the forest was mixed ponderosa pine [*Pinus ponderosa*] and Douglas fir. Timber harvesting on 23% of the area (removal of 26% of the basal area, in 1976) and 33% of the area (removal of 45% of the basal area, in 1982) had only small effects on selected streamflow parameters and these were not statistically significant. Therefore, a deterministic, physically based and distributed model was used as a method to estimate the effects of harvesting on streamflow. The model results indicate a small increase in water yield. The predicted snowmelt hydrographs also showed increases in peak streamflows and an advance of peak flow earlier in the melt season.

**Riha, S.J.; Campbell, G.S. 1985: Estimating water fluxes in Douglas fir plantations. Canadian Journal of Forest Research 15: 701–707.**

| Country: United States | Duration: 1 year | Report Location: LKR |
|---|---|---|
| Stand Type: Second-growth forests 7 & 9 yr | | |
| Keywords: Water balance | | |

*CAB Abstracts AN F049869*

A model was developed to estimate water fluxes in Douglas fir plantations using daily measurements of precipitation and maximum and minimum air temperatures. Soil water flow was modelled using a one-dimensional finite element solution to the Richards equation, with precipitation and root uptake of water included as source and sink terms. Soil hydraulic properties varied as a function of depth. Root uptake of water was based on an analogue water uptake model modified to include root resistance and cylindrical flow of water. Potential evapotranspiration was calculated assuming that leaf and air temperature did not differ and that stomatal conductance was dependent on the vapour density deficit of the air. Model validity was tested by comparing predictions (calculated by computer) with field measurements of soil water content make in the summer of 1978 at two locations in western Washington. In general, the model predicted the observed drying of the soil. Aspects of the simulated water budget for these Douglas fir stands considered most significant were: (1) the use of soil-stored water for transpiration in the summer, (2) the net flux of water into the root zone from deeper in the soil during the summer, (3) the dependence of water reaching the soil in the summer on the intensity of rainfall, (4) the large percentage of the total transpiration that occurred in spring and fall, and (5) the large amount of water moving out of the soil profile in the winter.

*Comment*

**Simulated water balances**

| Fluxes (mm) | 7-yr-old | 9-yr-old |
|---|---|---|
| Precipitation | 1660 | 1410 |

| | | |
|---|---|---|
| Interception | 260 | 440 |
| Transpiration | 640 | 560 |
| Runoff | 0 | 100 |

**Rothacher, J. 1963: Net precipitation under a Douglas fir forest. Forest Science 9: 423–429.**

| | | |
|---|---|---|
| Country: United States | Duration: 3 yr | Report Location: R870 |
| Stand Type: Old-growth; 300-yr & a 100-yr stand | | Rainfall: MAP 2330 mm |
| Keywords: Throughfall | | |

*CAB Abstracts AN 2503159*

A study carried out over 2 yr in 300-yr-old stands in the Washington–Oregon region showed that 96% of the variation in throughfall (T) during the summer (May–Sept.) was explained by a linear relation with storm size. During this period, T amounted to 76% of gross precipitation (P), reaching 82% in storms of > 3 in. rainfall. Stand density, ranging from 75 to 92%, had some influence on interception; stemflow (0.27% of P) was negligible. A weighted mean regression from these plots, chosen as the most useful for predicting the local summer throughfall, is T=0.8311 × P-0.0460 (Summer storms basis). Correlations for winter T were not determined. T increased at this season to a mean of 86.3%.

*Comment*

The following data are converted from imperial measurements. Amounts of precipitation were not stated.

Plot 1: 12 months PTTN = 2130 mm; Throughfall = 1670 mm (78%); Stemflow 6 mm (0.3%)
For 2 ½ summers Throughfall = 70.5% of precipitation
For 3 winters Throughfall = 86.3% of precipitation

For 2 ½ summers, average throughfall of six plots = 76% of PTTN.
For summer storms only T=0.8311 × P - 1.17

**Rothacher, J. 1965: Streamflow from small watersheds on the western slope of the Cascade Range of Oregon. Water Resources Research 1: 125–134.**

| Country: United States | Duration: | Report Location: R144 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Old-growth natural forest | | Rainfall: MAP 2390 mm |
| Keywords: Low flow; Storm flow; Water yield | | |

*CAB Abstracts AN 2701666/ Author's Abstract*

Streamflow from small watersheds on the western slopes of the Oregon Cascade Range is strongly influenced by a maritime climate (wet winters and dry summers). Although annual precipitation is high (94 inches in the study area), overland flow is almost unknown. Peak flows result largely from subsurface flow and under conditions in which both retention and detention reservoirs are almost filled during extended periods of low-intensity rainfall. Under these conditions, vegetation appears to exert a minimum influence on high streamflow. Lowest streamflow occurs from late August to mid-November and may follow a 60- to 100-day period with little or no rain. The dense vegetation of this part of the Douglas fir region appears to exert its major influence at such times. Removal of vegetation from only 30% of a 250-acre watershed has caused a 12–28% increase in minimum streamflow. On a 237-acre watershed on which 80% of the trees were cut, the increase in low flow was 85%.

*Comment*

H J Andrews Watersheds 1,2,and 3

Predominantly winter rainfall on a wet catchment = 2400 mm/yr.

At watershed 2, RO = 0.931 × PTTN − 668 mm. MAP = 2388 mm has RO = 1550 mm. For the same rainfall, Watersheds 1 and 3 yield 1370 and 1345 mm.

Post-harvest:

WS 3, 8% roaded, left for 3 yr and then 25% harvested and burned, showed no increase in peak flows after roading or after logging. 12–28% increase in minimum flows over 6 yr with 22% the first year after harvesting being no greater than the fourth year after roading.

WS1, harvested over a number of years. Low flows increased 45% after 40% cut, and 85% the next year when 80% cut. The increases are equivalent to 0.02 to 0.1 mm/day.

**Rothacher, J. 1970: Increases in water yield following clear-cut logging in the Pacific Northwest. Water Resources Research 6: 653–658.**

| Country: United States | Duration: 17 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Old-growth natural forest − 10 to + 7 yr | | Rainfall: MAP 2390 mm |
| Keywords: Storm flow; Water yield | | |

*CAB Abstracts AN 3200076*

Studies in three small catchment areas in Douglas fir forests [cf. F.A. 29 No. 3316] that had been patch-cut, more extensively clear-felled, or left undisturbed, suggest that increases in water yield are roughly proportional to the proportion of the area cleared. In the high-precipitation region of the Oregon Cascades, clear-felling can increase water yield by 18 in./yr, most of the increase occurring between Oct. and March, but there were no noticeable changes in storm flow, and some of the low-flow late summer increases were important. On large catchments managed for sustained yield the increases might be largely obscured. The duration of logging effects, effect of regrowth, etc. are briefly discussed.

*Comment*

**Treatments at H J Andrews Experimental Forest, Oregon.**

| | Control | Patch-cut | Cleared |
|---|---|---|---|
| Area (ha) | 61 | 101 | 96 |
| Cutting (%) | 0 | 30 | 100 |

Does not produce actual flows/yields but shows predicted changes.

100% clear-cut: Noted an increase in yield when over 40% cut. The 2 yr after burning had increased yields of 460 mm. Seasonal increases were significant. Biggest were in autumn during the first major rains. No noticeable change in flood peaks in the biggest storms.

Patch-cut: yield increase of about 150 to 300 mm.

**Rothacher, J. 1971: Regimes of streamflow and their modification by logging. *In*: Krygier, J.T.; Hall,J.D. (eds). Forest Land Uses and Stream Environment, Oregon State University. Corvallis. Pp. 40–54.**

| | | |
|---|---|---|
| Country: United States | Duration: 17 yr | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: Old-growth natural forest − 10 to + 7 yr | | Rainfall: MAP 2390 mm |
| Keywords: Low flow; Storm flow; Water yield | | |

*Comment*

H J Andrews Experimental Forest, Oregon. Provides much of the same data as Rothacher (1970). Does not produce actual flows/yields but shows predicted changes.

Generally increased flow after harvesting, no change in larger flood peaks, increased minimum flows

**Rothacher, J. 1973: Does harvest in west-slope Douglas fir increase peak flow in small streams.? USDA Forest Service Research Paper PNW-163.**.

| Country: United States | Report Location: Not sighted |
|---|---|
| Land-Use Change: Harvesting | |
| Stand Type: Old-growth natural forest | |
| Keywords: Storm flow | |

*Comment*
Not found in the New Zealand library system

**Rutter, A.J.; Morton, A.J.; Robins, P.C. 1975: A predictive model of rainfall interception in forests. II. Generalization of the model and comparison with observations in some coniferous and hardwood stands. Journal of Applied Ecology 12: 367–380.**

| Country: England | Duration:18 months | Report Location: LKR |
|---|---|---|
| Species comparison: Conifers; Native deciduous forest; Pine species | | |
| Stand Type: Plantation | | |
| Keywords: Interception; Model; Stemflow | | |

*CAB Abstracts AN: 751918683/Author summary*

A previously published model of rainfall interception by forests was generalised, and elaborated to enable separate calculation of throughfall and stemflow. Calculated mean interception loss per month was within 10% of the observed means (for periods of from 8 to 18 months) in *Pinus nigra,* Douglas fir*, Picea abies* and *Carpinus betulus*. In an old coppice of *Quercus robur* mean monthly interception loss was underestimated by 20% and in artificially defoliated plots in the same coppice, by 32%. The correlation coefficient between observed and calculated monthly totals of interception loss was about 0.9 in five of the stands and 0.82 in the defoliated *Q. robur*. The ability of the model to account for differences in interception loss between different species in the same climate, between the leafy and leafless condition in deciduous stands, and for stemflow and evaporation from trunks, is discussed.

*Comment*
Uses a modification of the Rutter et al. (1975) model.
Corsican pine and Douglas fir stands were adjacent; the others some distance away.

Stemflow negligible in Corsican pine, 7.7% of gross precipitation for Douglas fir.
For Douglas fir, canopy storage is 1.2 mm, trunk storage is 0.9 mm
On a monthly basis:

| | |
|---|---|
| Douglas fir | IL = 0.83 + 0.283 × PTTN |
| Corsican Pine | IL = 0.63 + 0.226 × PTTN |

**Interception by Douglas fir and other species**

| Stand | Mean monthly rainfall (mm) | Interception loss (mm) | Interception loss (%) |
|---|---|---|---|
| Corsican pine | 65.3 | 23.05 | 35 |
| Douglas fir | 65.3 | 25.5 | 39 |
| Norway spruce | 29.8 | 14.3 | 48 |
| Hornbeam | 37.2 | 13.35 | 36 |
| Oak (control) | 56.1 | 10.2 | 18 |
| Oak (defoliated) | 56.1 | 6.6 | 12 |

**Schaap, M.G.; Bouten, W. 1997: Forest floor evaporation in a dense Douglas fir stand. Journal of Hydrology 193: 97–113.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 50 days in 1 yr | Report Location: R879 |
| Stand Type: Plantation 31yr | Stand Density: 992 SPH | Basal Area: 33.4 $m^2$/ha |
| Height: 21 m | | Rainfall: MAP 834 mm. |
| Keywords: Evaporation | | |

*CAB Abstracts AN 971912092/ Authors' Abstract*

Forest floor evaporation was measured with an accurate weighing lysimeter during 44 days in early spring and summer in a dense Douglas fir stand in central Netherlands. The Penman-Monteith approach was used to model the evaporation rates as well as the temperature difference between forest floor surface and air at 1 m height. Values of resistance parameters were slightly different when the Penman-Monteith model was optimised for measured evaporation rates or for measured temperature differences. These discrepancies were partly due to field variability in forest floor water contents but also because the approach considered the forest floor to be isothermal. With the appropriate parameter sets, the model was able to predict measured hourly forest floor evaporation rates and surface temperature dynamics satisfactorily. The Penman-Monteith ventilation term dominates over the available energy term in the forest studied. As a result the evaporation flux is matched by an almost equal sensible-heat-flux but in opposite direction. Forest floor water-content dynamics have a strong control over the evaporation flux. Spatial variability in forest floor water contents cause the 44-day average forest-floor evaporation to range from 0.19 mm/day in a dry part of the forest to 0.3 mm/day in a wet part with 0.23 mm/day as a site representative value.

**Schaap, M.G.; Bouten, W.; Verstraten, J.M. 1997: Forest floor water content dynamics n a Douglas fir stand. Journal of Hydrology 201: 367–383.**

| Country: The Netherlands | Report Location: R882 |
|---|---|
| Stand Type: Plantation | |
| Keywords: Evaporation; Soil water | |

*CAB Abstracts AN 981903175/Authors' Abstract*

The hydrology of the forest floor within a homogeneous Douglas fir forest in The Netherlands was considered. Time domain reflectometry measurements showed that forest floor water contents had considerable spatial variabilities but similar temporal dynamics. Simple linear relations could be used to translate forest floor water-content dynamics from one site in a forest to another. Forest floor evaporation rates were calculated using a previously developed forest floor evaporation model and a year of soil water and micrometeorological data. For a relatively wet site within the stand the calculated evaporation rate was 137 mm/yr, for a more representative site 112 mm/yr, and for a dry site 76 mm/yr. These amounts ranged between 7 and 13% of the total yearly forest evapotranspiration. Together with throughfall rates and transpiration rates, these forest floor evaporation rates served as boundary conditions to a soil water model with which forest floor and mineral-soil water-content dynamics were simulated. The simulations showed that throughfall and drainage dynamics determined the forest floor water content dynamics in wet conditions. In dry periods, forest floor evaporation and, to a lesser extent, root water uptake, determined forest floor water-content dynamics. The same simulations showed that 25% of the forest floor evaporation was replenished by capillary rise from the mineral soil.

**Schowalter, T.D. 1999: Throughfall volume and chemistry as affected by precipitation volume, sapling size, and defoliation intensity. Great Basin Naturalist 59: 79–84.**

| Country: United States | Duration: 2 yr | Report Location: LKR |
|---|---|---|
| Stand Type: Plantation 9 yr | | |
| Keywords: Throughfall | | |

*CAB Abstracts AN 990603198/Author's Abstract*

Throughfall and stemflow are important components of hydrologic processes in forests, but relative contributions of multiple factors, including precipitation volume, plant size, and herbivory, on throughfall/stemflow have not been reported. This paper reports the relative influences of precipitation volume (0–230 L/m$^2$), sapling size (1.4–6.7 cm diameter at root collar; 0.07–0.45 kg calculated dry foliage mass), and manipulated herbivory (0–20% foliage removal) on throughfall volume and N, K, and Ca fluxes as evaluated with stepwise multiple regression in a young Douglas fir ecosystem at Andrews Forest, Oregon, United States. Precipitation volume explained most variation in throughfall volume ($R^2$ = 0.81). Herbivory and sapling size each had significant but minor effects on throughfall volume and nutrient fluxes. The data indicated that herbivore effects, while significant, are masked by precipitation in this wet ecosystem. Wider ranges in sapling size and herbivory and/or drier conditions were considered likely to improve interpretation of their influence on throughfall volume and chemistry.

*Comment*

H J Andrews Watershed 10.
Throughfall refers to the amount of water collected under the sapling crown and as stemflow, and does not take into account direct precipitation through canopy gaps as is normally done. Nothing here converts the data to meaningful 'throughfall' on a stand basis.

**Spittlehouse, D.L. 1986: Relating forest meteorology to the forester. IUFRO, Yugoslavia 1986. Vol 1: 50–60**

| | |
|---|---|
| Country: Canada | Report Location: RJJ |
| Keywords: Evaporation; Model | |

*Comment*

A discussion of the need, problems and solutions in providing meteorological information for foresters with examples of their successes. Using evapotranspiration models is one example illustrating how differing models are used to suit the circumstances.

'The modeling of evapotranspiration is an overstudied aspect of forest and agricultural meteorology. The literature abounds with evapotranspiration models, most of which are basically the same. Apart from specific problems such as within-canopy flow and evaporation, and the coupling of the surface and planetary boundary layers, the main problem lines in applying the models in forest management. We have attacked the problem by using two types of models. Each has its uses and neither is expected to work in all situations.'

The first model is for limited data and one to six-day time steps and using a crop factor — for an example see Giles et al. (1985). The other model is based on the Penman-Monteith equation, has explicit LAI and stomatal resistance, and has been used by Kelliher et al. (1986).

**Spittlehouse, D.L.; Black, T.A. 1979: Determination of forest evapotranspiration using Bowen ratio and eddy correlation measurements. Journal of Applied Meteorology 18: 647–653.**

| | |
|---|---|
| Country: Canada | Report Location: Not sighted |
| Stand Type: Plantation | |
| Keywords: Evaporation; Model | |

*CAB Abstracts AN: 791949967*

Rates of evapotranspiration from a 14-m-high Douglas fir forest on the south-west coast of British Columbia were obtained by means of the energy balance/Bowen ratio method and an energy balance/eddy correlation method. In the former method, the Bowen ratio was measured with reversing diode psychrometers. In the latter, the sensible heat flux was obtained by eddy correlation analysis of data obtained from a fast response thermistor and Gill anemometers mounted horizontally and at 30 degrees from the vertical. The generally low wind speed above the forest resulted in occasional stalling of the anemometers and made the obtaining of adequate eddy correlation data difficult. Spectral analysis of the eddy correlation data indicates that a significant fraction of the sensible heat flux was at low frequencies. The experiment suggests that an eddy correlation system using mechanical anemometers is not suitable for extended water balance studies of forests where low wind speeds predominate.

**Spittlehouse, D.L.; Black, T.A. 1981: A growing season water balance model applied to two Douglas fir stands. Water Resources Research 17: 1651–1656.**

| | | |
|---|---|---|
| Country: Canada | Duration: 5 yr | Report Location: R408 |
| Land-Use Change: Forest management | | |
| Stand Type: Plantation 21, 25 & 26 yr | Stand Density: 1840 and 830 SPH | |
| Height: 9 & 12.5 m | | |
| Keywords: Evaporation; Model | | |

*CAB Abstracts AN 841990280 /Authors' Abstract*

The forest water-balance-model presented requires only daily solar radiation, maximum and minimum air temperature, and rainfall as the input weather data. Site parameters are root zone depth, soil water retention and drainage characteristics, estimated canopy leaf area index, and the coefficients of the evapotranspiration and rainfall interception submodels. The evapotranspiration submodel calculates the forest evapotranspiration rate as the lesser of energy-limited and soil-limited rates. The former is calculated from the 24-hour net radiation and the latter from the fraction of extractable water in the root zone. Solar radiation and air temperature are used to calculate net radiation. Interception is calculated from the daily rainfall. The root zone is treated as a single layer with drainage calculated as a function of the root-zone water content. Water deficits and the matric potential of the root zone are used to indicate tree water stress. The model was tested on two Douglas fir stands of different stand density and leaf area index. The coefficients used in the evapotranspiration submodel were found to be the same for both stands. It was also found that over 20% of the growing season rainfall was lost through interception.

*Comment*

Modelled interception:
Site 1, age 21 unthinned, mid-June to mid-August 19% of PTTN (amount not stated).
Site 2 ages 25 and 26, thinned, May to September/October 24 and 23% of PTTN (amount not stated).

When trees are not undergoing soil moisture stress, in mid-summer E is about 3 mm/day but drops to about 0.5 mm/day as moisture stress increases.

**Stednick, J.D. 1996: Monitoring the effects of timber harvest on annual water yield. Journal of Hydrology 176: 79–95.**

| Country: USA | Report Location: R33 |
|---|---|
| Species Comparison: Conifers; Native deciduous forest; Pines; Scrubland | |
| Land-Use Change: Afforestation; Conversion; Harvesting | |
| Stand Type: Natural & regrowth forest | |
| Keywords: Review; Water yield | |

*Comment*
Reviews paired catchment studies in the USA.and updates Hewlett & Hibbert (1967) and Bosch & Hewlett (1982). Includes the work of Harr, Rothacher and Harris which are listed elsewhere in this report. See the paper to get back to the appropriate original data

**Increase in streamflow after harvesting Douglas fir and Douglas fir/mixed forest**

| Catchment | Area | MAP (mm) | Streamflow (mm) | % Cut | Streamflow increase (mm) |
|---|---|---|---|---|---|
| Coyote Creek #1 | 69 | 1230 | 630 | 50 | 60 |
| Coyote Creek #2 | 68 | 1230 | 630 | 30 | 119 |
| Coyote Creek #3 | 50 | 1230 | 630 | 100 | 360 |
| Fox Creek #1 | 59 | 2730 | 1750 | 25 | 0 |
| Fox Creek #3 | 71 | 2730 | 1750 | 25 | 0 |
| Deer Creek | 303 | 2480 | 1910 | 25 | 150 |
| NeedleBranch | 71 | 2480 | 1885 | 82 | 615 |
| HJ Andrews #1 | 96 | 2390 | 1380 | 100 | 462 |
| HJ Andrews #3 | 101 | 2390 | 1380 | 30 | 297 |
| HJ Andrews #6 | 13 | 2150 | 1290 | 100 | 425 |
| HJ Andrews #7 | 21 | 2150 | 1290 | 600 | 240 |
| HJ Andrews #10 | 96 | 2330 | 1650 | 100 | 400 |

**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 year | Report Location: R1598 |
|---|---|---|
| Species Comparison: *Pinus radiata*; Pine species | | |
| Stand Type: Plantation various ages | | Stand Density: Various |
| Keywords: Transpiration | | |

*Comment*
Transpiration measured by sap flux 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 1973–1974**

**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:
*P. radiata* 700–1000 mm >> *P. contorta* 350–560 mm >< Douglas fir 140–850 mm.

Comments that sap flux in *P. radiata* decreases with age and stabilises at 13–16 $cm^3/cm^2$/hour. 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.

**Thomas, R.B.; Megahan, W.F. 1998: Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon: A second opinion. Water Resources Research 34: 3393–3403.**

| Country: United States | Report Location: R1353 |
|---|---|
| Land-Use Change: Harvesting | |
| Stand Type: Old-growth forests | |
| Keywords: Storm flow | |

*Comment*
Re-evaluates the work of Jones & Grant (1996) having criticised their methods. Considers three small catchments at HJ Andrews and six larger catchments.

‘We could not detect any effects of cutting on peakflows in one of the large basin pairs, and results were inconclusive in the other two large basin pairs.’

‘Peak flows were increased up to 90% for the smallest peak events on the clear-cut watershed and up to 40% for the smallest events in the roaded and patch-cut watershed. Percentage treatment effects decreased as flow event size increased and were not detectable for flows with 2-yr return intervals or greater on either treated watershed. Treatment effects decreased over time but were still found after 20 yr on the clear-cut watershed but only for 10 yr on the patch-cut and roaded watershed.”

**Tiktak, A.; Bouten, W. 1994: Soil water dynamics and long-term water balances of a Douglas fir stand in the Netherlands. Journal of Hydrology 156: 265–283.**

| Country: The Netherlands | Duration: 30 yr | Report Location: R878 |
|---|---|---|
| Stand Type: Plantation | | |
| Keywords: Evaporation; Interception; Model; Water balance | | |

*CAB Abstracts AN 950602133/Authors’ Abstract*

Seasonal dynamics of soil water, the annual water balances over a period of 30 yr (1960–90) and the frequency of occurrence of extreme water shortage were quantified with the model 'SWIF' for a Douglas fir stand on a sandy soil in the central Netherlands. The stand was 29 yr old at the beginning of 1988. The hydrological information was needed for evaluating the impact of air pollution and water shortage on forest growth, and to calculate chemical budgets. Measurements necessary for model parameterisation included rainfall, throughfall, transpiration, soil water content and soil water pressure head. These data were available for 3 yr. For the period without measurements, throughfall and potential evapotranspiration were calculated from synoptic weather data with an empirical model. The effect of using synoptic weather data instead of detailed on-site measured data was analysed. The results showed that after calibration of the empirical model

the simulated annual water balance and seasonal soil water dynamics were well described with synoptic weather data as well as with detailed on-site measured data. The modelled annual water balances for the period 1960–90 are presented as cumulative frequency distributions. Median values of the major terms of the water balance and the frequency of occurrence of extreme water shortage were derived from these diagrams. Annual median precipitation was 834 mm, calculated median interception loss 317 mm, median transpiration 363 mm, median soil water evaporation 32 mm and median vertical drainage at 150 cm depth 195 mm. The sum of the major losses was not equal to median annual precipitation as the median values of the individual terms may occur in different years. Transpiration shows smaller variations (11%) between the years than throughfall (54%) and vertical drainage (112%). Although the median value of transpiration reduction resulting from water stress was low (4%), some years showed extreme water shortage, the highest transpiration reduction being 31% for 1976. Although total transpiration reduction during median years was low, short periods with considerable drought stress occur during these years.

*Comment*
Describes the SWIF model and models the water balance for the stand over 30 yr.
Mean water balance: PTTN 647 mm; IL 246 mm; Transpiration 347 mm; Soil evaporation 29 mm.

**van Ek, R.; Draaijers, G.P.J. 1994: Estimates of atmospheric deposition and canopy exchanges for three common tree species in The Netherlands. Water, Air, and Soil Pollution 73: 61–82.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 1 yr | Report Location: LKR |
| Species Comparison: Native deciduous forest; Pine species | | |
| Stand Type: Plantation 35 yr | Stand Density: 662 SPH | |
| Height: 27 m | Diameter: 23.5 cm | Rainfall: MAP 790 mm |
| Keywords: Throughfall | | |

*CAB Abstracts AN: 950602087*

During 1 yr (1989), dry and wet deposition onto 30 forest stands was studied by sampling throughfall and bulk precipitation. Nine measurement sites were situated in Douglas fir stands, 10 in Scots pine (*Pinus sylvestris*) stands and 11 in oak (*Quercus robur*) stands. Because the stands were situated in each other's proximity (i.e. within a radius of approximately 1.4 km) it is assumed that they experienced an approximately equal air pollution load. For the acidifying compounds $SO_4^{--}$, $NO_3^-$ and $NH_4^+$, spatial variability in wet deposition was small within the area studied. Dry deposition, as estimated by net throughfall, displayed a much higher spatial variability. Significant differences existed between tree species and growing seasons. Douglas fir mostly displayed the highest, oak the lowest and Scots pine intermediate values for net throughfall fluxes of acidifying compounds. The annual net throughfall fluxes for nitrogen compounds were significantly higher for the coniferous tree species than the broadleaved tree species. For $SO_4^{--}$, however, oak showed a relatively high throughfall flux during the summer. By comparing the temporal pattern of net throughfall fluxes between the three tree species it was concluded that considerable canopy leaching occurred for $SO_4^{--}$, $Mg_2^+$, $PO_4^{---}$, $HCO_3^-$ and $K^+$ in oak stands during the sprouting of leaves in spring. From surface wash experiments in the laboratory it is concluded that canopy leaching of these ions may also be enhanced when oak leaves are infected by oak mildew — a fungal disease caused by *Microsphaera alphitoides*.

*Comment*

Three species: Douglas fir (9 stands), Scots pine (10 stands), Oak (11 stands).
All plantations within a radius of 1.4 km. Data pooled for each species.
Stemflow not measured.

**One-year throughfall**

| | Douglas fir | Scots pine | Oak |
|---|---|---|---|
| Precipitation (mm) | 714 | 714 | 714 |
| Throughfall | 523 | 606 | 640 |
| Throughfall % | 75 | 85 | 90 |

**van Wijk, M.T.; Dekker, S.C.; Bouten, W.; Kohsiek, W.; Mohren, G.M.J. 2001: Simulation of carbon and water budgets of a Douglas fir forest. Forest Ecology and Management 145: 229–241.**

| | | |
|---|---|---|
| Country: The Netherlands | Duration: 2 yr | Report Location: LKR |
| Land-use change: Forest management | | |
| Stand Type: Plantation 33–34 yr | Density: 780 SPH unthinned; ~520 after thinning | |
| Height: 21.6+ m | | |
| Keywords: Evaporation; Interception; Model; Water balance | | |

*Comment*

Used the FORGRO-SWIF model. Stand LAI varied between 7.8 and 10.5 before thinning when 1/3 of the vegetation was removed. Gives simulations for the two stands for 10 years.

**Simulated water balances in (mm); rain and soil evaporation are common to both sets**

| Year | PTTN | Non-thinned | | | | Soil evapor -ation | Thinned | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | INTN | TRANS | Drainage | Storage change | | INTN | TRANS | Drainage | Storage change |
| 1988 | 880 | 400 | 390 | +20 | −10 | 70 | 360 | 220 | 240 | −10 |
| 1989 | 800 | 360 | 400 | −30 | 0 | 70 | 330 | 230 | 170 | 0 |
| 1990 | 870 | 400 | 410 | −30 | +20 | 70 | 360 | 240 | 180 | −20 |
| 1991 | 780 | 350 | 350 | −40 | +40 | 70 | 320 | 220 | 160 | +10 |
| 1992 | 1000 | 450 | 420 | +30 | +30 | 70 | 410 | 230 | 310 | 0 |
| 1993 | 1040 | 470 | 390 | +50 | +60 | 70 | 430 | 210 | 280 | +50 |
| 1994 | 1020 | 460 | 400 | +120 | −30 | 70 | 420 | 220 | 320 | −10 |
| 1995 | 740 | 330 | 380 | +90 | −130 | 70 | 300 | 220 | 200 | −50 |
| 1996 | 670 | 300 | 280 | −50 | +80 | 70 | 270 | 200 | 80 | +60 |
| 1997 | 740 | 330 | 390 | −40 | −10 | 70 | 300 | 230 | 110 | +30 |

Interception is about 45% of precipitation which is only 10% lower than transpiration. After thinning, the simulation has interception decreasing to about 40% of rainfall, transpiration decreased of the order of 40%, and there is a significant increase in soil drainage after thinning.

**Will, G.M. 1959: 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 |
|---|---|---|
| Species Comparison: Conifers; *Pinus radiata*; Pine species | | |
| Stand Type: Plantation 33 yr | Stand Density: 1240 SPH | Height: 27 m |
| Keywords: Nutrient cycling; Throughfall | | |

*Comment*

Kaingaroa Forest:Two rain collectors (140 mm glass funnels) at each site.
Douglas Fir, 33 year 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 |

**Wright, K.A.; Sendek, K.H.; Rice, R.M.; Thomas, R.B. 1990: Logging effects on streamflow: storm runoff at Caspar Creek in northwestern California. Water Resources Research 26: 1657–1667.**

| Country: United States | Duration: 19 yr | Report Location: LKR |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Second growth with redwoods | | |
| Keywords: Storm flow | | |

*CAB Abstracts AN 940600292*

The effects of road building and selective tractor logging of second-growth *Sequoia sempervirens* and Douglas fir on total storm volumes, quickflow volumes, peak flows and lag times were studied for a small (424 ha) coastal watershed in northern California.

*Comment*

Tabulates results from a number of papers (some included here and others not obtainable) on the effects of road building and logging on stormflows in the US Pacific Northwest. Presents data from the North (control) and South Forks subcatchments (4.5% roads, 100% clear-cut) of Caspar Creek.

Used storms that fitted the following criteria:
1 A peak flow >0.056 L/s/ha
2 Complete records for the control and treated catchments
3 Storm pairs that approximately corresponded with time
4 Storm with an initial rise greater than the Hewlett & Hibbert (1967) separation line.

Variable determined using the Hewlett & Hibbert separation were: initial flow, peak flow, flow at end of quickflow, quickflow, and total flow from start of rise to the end of quickflow. Time periods analysed were the calibration period, 4-yr post-roading/pre-logging and 10-yr post-logging. The data from the treated catchments were regressed against those from the control for these three periods.

No change in total volume, quickflow volume or peak flow were found for the post-roading period — the roads occupied 4.5% of the catchment. There were significant differences in the calibration and post-logging regression for the same variable post-logging.

Small storm peaks (< 1.33 L/s/ha) increased 111% after logging; and volumes in very small storms (< 0.27 mm) increased 132%. For large storms (less frequent than 8/yr) showed no detectable increases.

**Ziemer, R.R. 1981: Storm flow response to road building and partial cutting in small streams of Northern California. Water Resources Research 17: 907–917.**

| Country: United States | Duration:13 yr | Report Location: R151 |
|---|---|---|
| Land-Use Change: Harvesting | | |
| Stand Type: Second growth with redwoods | | |
| Keywords: Storm flow | | |

*Author's Abstract*

To assess the influence of road building and logging on storm flow response, a pair of watersheds were studied at Caspar Creek near Fort Bragg in northern California from 1963 to 1975. Selection cutting and tractor yarding of 85-yr-old second-growth redwood and Douglas fir forest did not significantly affect large peak streamflows. The first streamflow peaks in the fall, however, were increased about 300% after logging. These early fall storms produced small peaks, which had little, if any, hydraulic consequence. The effect of logging on peak flow was best predicted by a variable representing the percentage of the area logged divided by the sequential storm number within the year.

*Comment*

Also Caspar Creek, North Fork and South Fork.

Showed there were slight changes by way of a break in slope in a mass curve of cumulative peak flows once harvesting took place. Regression lines of relationships for pre- and post-logging periods between the treated and control catchments were not significantly different. An analysis was done using derived variables over four flow classes and only the smallest showed any significant increase.

Noted that the first streamflow peaks in the fall were increased by about 300% after logging but because they were small they had little, if any, hydraulic consequence.

**Ziemer, R.R. 1998: Flooding and stormflows. *In*: Ziemer, R.R. (Technical Coordinator) Proceedings of the conference on coastal watersheds: The Caspar Creek story. USDA Forest Service General Technical Report PSW-GTR-168: 15–24.**

| | | |
|---|---|---|
| Country: United States | Duration:35 yr | Report Location: LKR |
| Land-Use Change: Harvesting | | |
| Stand Type: Second growth with redwoods | | |
| Keywords: Storm flow | | |

*Comment*
A continuation of the Caspar Creek story.
After South Fork was selection-cut, peak flows did not change significantly in those floods that occur about 8 times a year — larger than 1 L/s/ha. For events smaller than this, the first peaks in fall increased 300% but the second storm produced only half that response.

In a second phase in which North Fork was logged there was a mean peak flow increase of 35% in clear-cut subcatchments and 16% increase in partially cut subcatchments for the class of flows > 4 L/s/ha, i.e. those occurring less frequently than twice a year.

## Section 4: Additional References

These citations are referred to in the text but are not in Section 3.

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