Programa de Doctorado en Ciencias Forestales
Escuela de Graduados
Facultad de Ciencias Forestales

Revealing the impact of forest exotic plantations on water yield in large scale watersheds in South-Central Chile

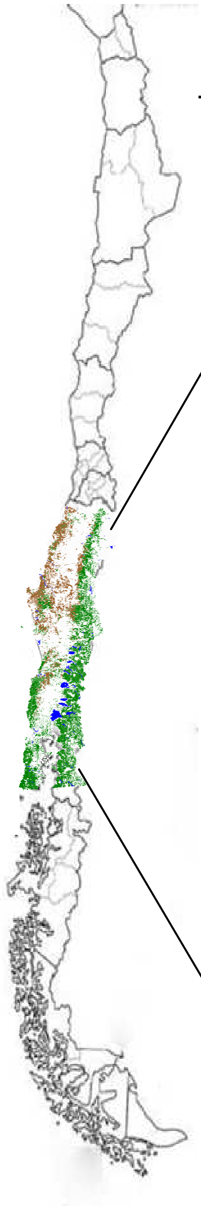
Christian Little, Antonio Lara, James McPhee, and Rocío Urrutia

Journal of Hydrology 374 (2009) 162–170

OUTLINE

- Motivation and objective
- Data and methods
- Results and discussion
- Summary

Motivation and objective



Motivation and objective

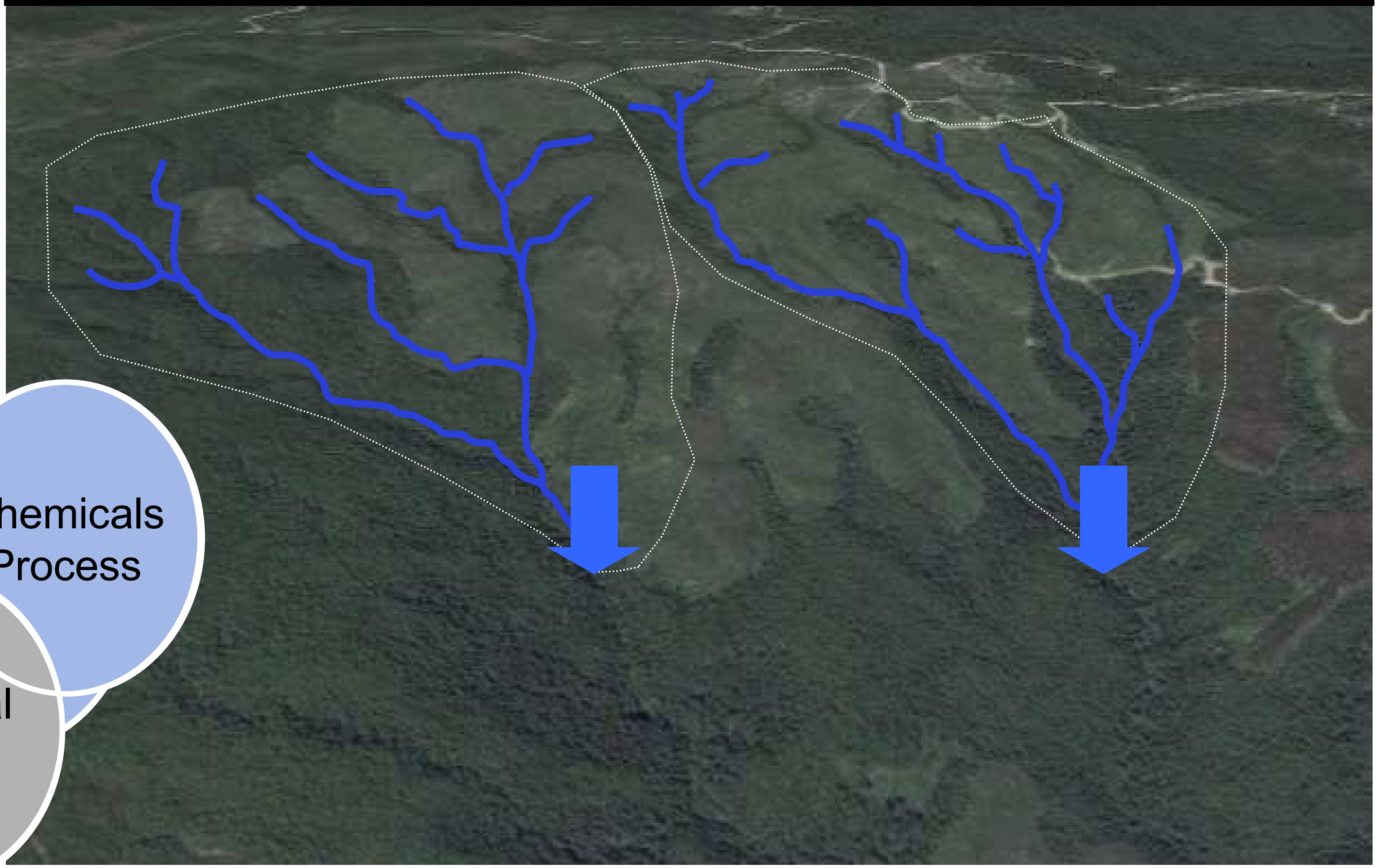
Progressive deterioration of native forest ecosystems related to public policies favouring forestry plantations of exotic species

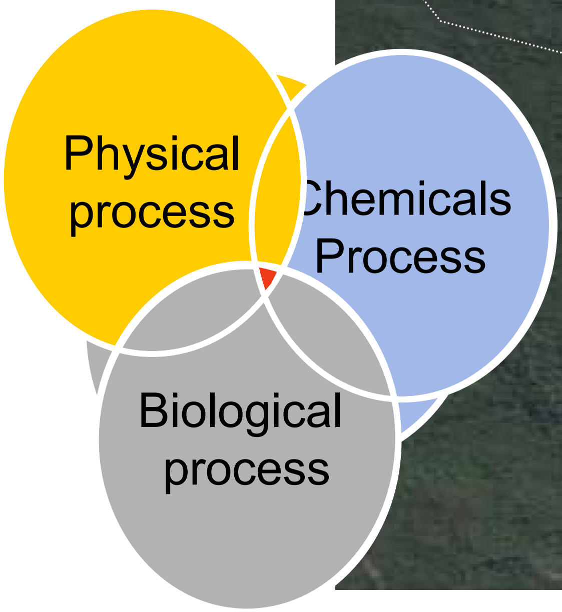
Public policy formulation has ignored ecosystem services from native forest (i.e. water quality and quantity), which can be measured in social and economic terms.

Very little research specific for Chile has been published with respect to water yield.

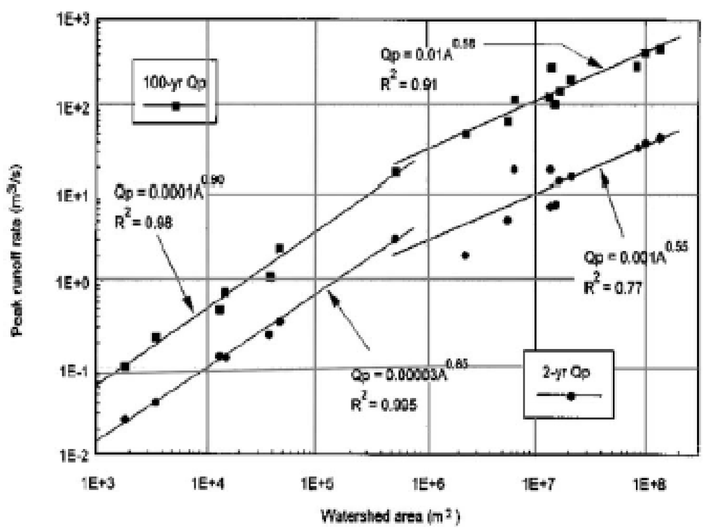
Motivation and objective

Water quality and quantity depends on runoff generation process

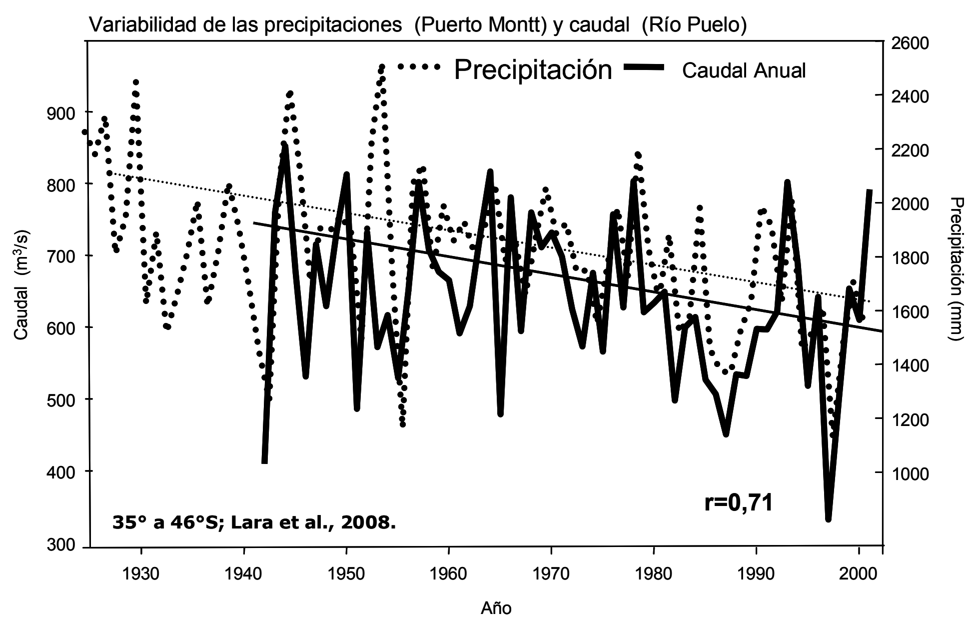




Motivation and objective

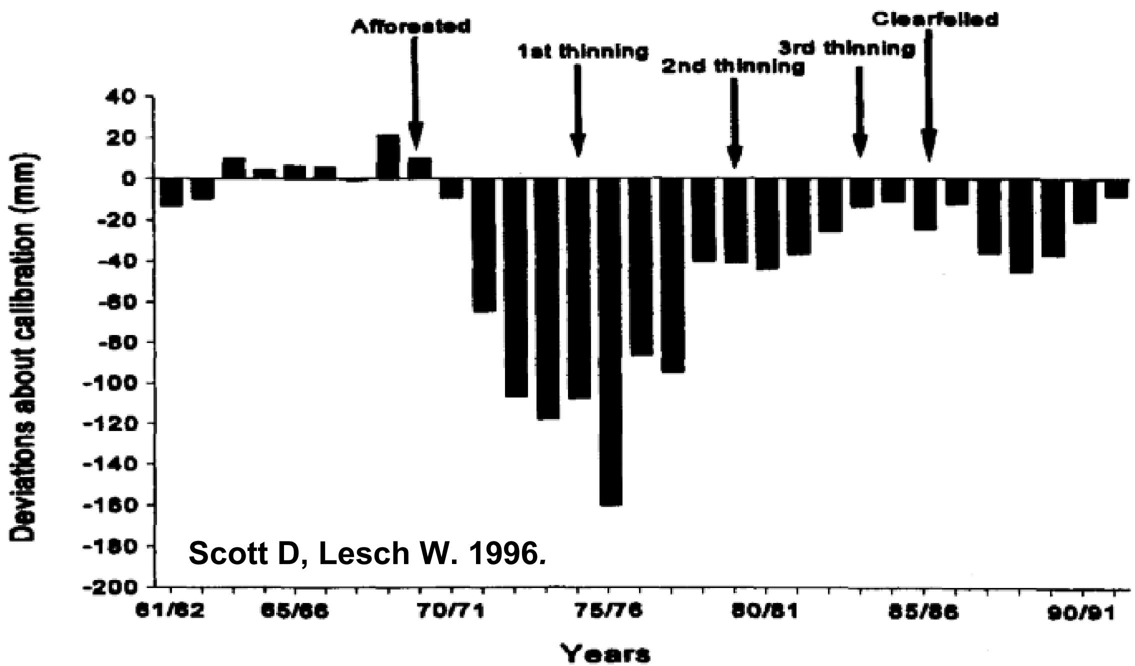


Gupta, V. 2006. Emergence of statistical scaling in foods on channel networks from complex runoff. Dynamics. Chaos, Solitons and Fractals. 19: 357–36.



Period of calibration

< 100 ha



Motivation and objective

Global Change Biology (2005) **11**, 1565–1576, doi: 10.1111/j.1365-2486.2005.01011.x

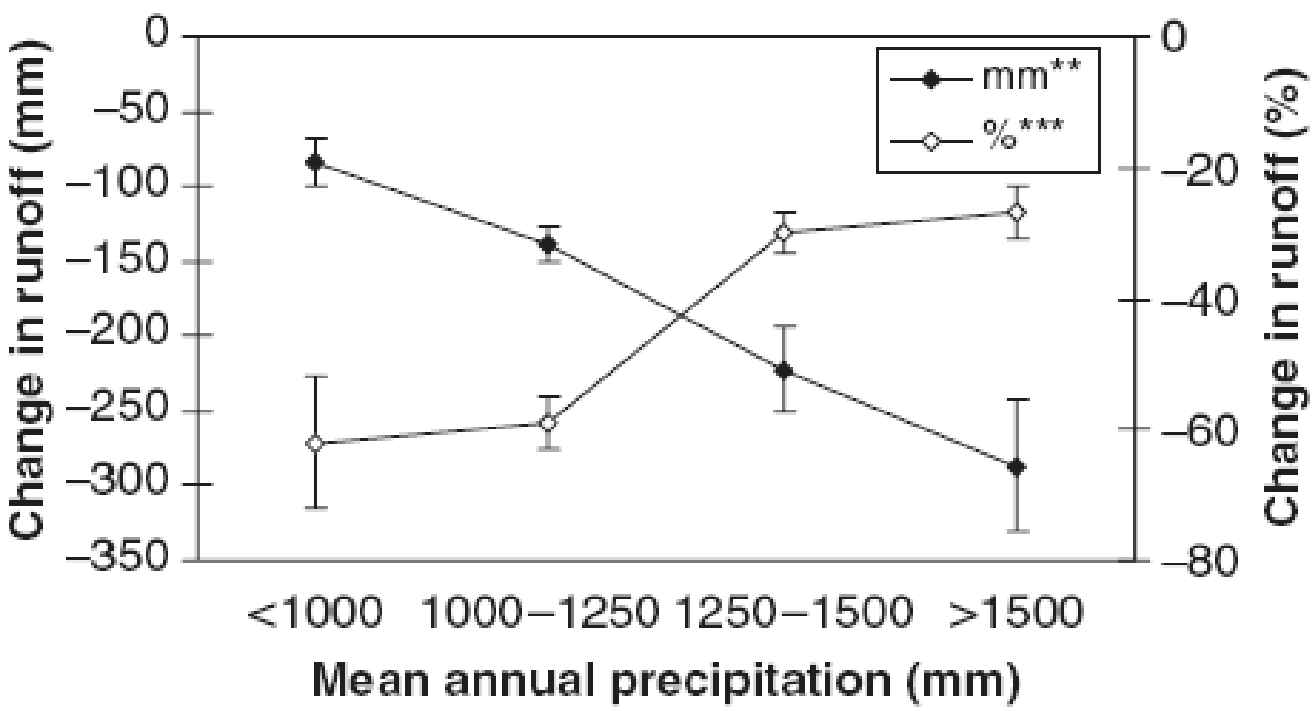
Effects of afforestation on water yield: a global synthesis with implications for policy

KATHLEEN A. FARLEY*†, ESTEBAN G. JOBBÁGY†‡ and ROBERT B. JACKSON*†

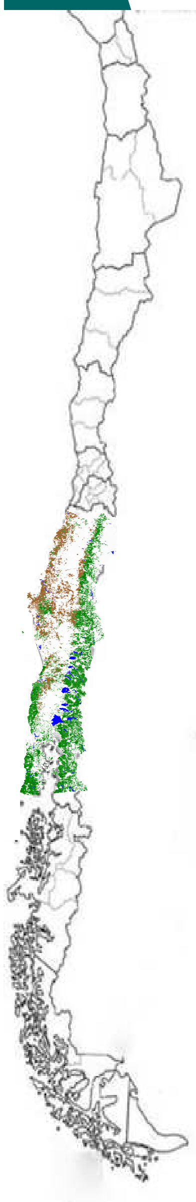
Table 1 Mean change in runoff (± SE) following afforestation, by original vegetation type and by planted vegetation type, averaged across plantations ≤ 30 years old

Afforested from	Afforested to	Change in runoff (%)	Catchment *n*	Change in runoff (mm)	Catchment *n*	MAP (mm)	Δrunoff (mm)/MAP (mm) (%)
Grassland	Any species	–44 (± 3)**	13	–170 (± 13)^{ns}	11	1241 (± 16)	15 (± 0.9)
Shrubland		–31 (± 2)**	8	–162 (± 8)^{ns}	8	1262 (± 10)	14 (± 0.6)
Grassland or shrubland	Pines	–35 (± 2)^{ns}	14	–165 (± 8)^{ns}	14	1236 (± 10)	14 (± 0.5)
	Eucalypts	–50 (± 5)^{ns}	4	–173 (± 20)^{ns}	4	1336 (± 23)	14 (± 1.7)
	Other species	–39 (± 7)^{ns}	3			1415 (± 33)	
Grassland only	Pines	–40 (± 3)*	9	–167 (± 13)^{ns}	9	1260 (± 18)	14 (± 0.9)
	Eucalypts	–75 (± 10)*	1	–202 (± 38)^{ns}	1	1166 (± 0)	19 (± 3.2)
	Other species	–39 (± 7)*	3			1415 (± 33)	
Shrubland only	Pines	–30 (± 2)^{ns}	5	–163 (± 9)^{ns}	5	1226 (± 9)	15 (± 0.6)
	Eucalypts	–38 (± 5)^{ns}	3	–159 (± 23)^{ns}	3	1414 (± 24)	12 (± 1.9)

Motivation and objective



Farley K, Jobbágy E, Jackson R. 2005.



Motivation and objective

Pizarro, R., Araya, S., Jordan, C., Farías, C., Flores, J-.Bj., Bro, P., 2006. The effects of changes in vegetative cover on river flows in the Purapel river basin of central Chile. Journal of Hydrology 327 (1–2), 249–257.

Table 1 Vegetation cover in variation in Purapel River Basin, 1960–2000

Classification	Area (ha)		
	1955	1978	1997
Native forest	16,737.9	13,698.8	5214.6
Pinus radiata	0.0	5115.5	13,677.9
Meadows	2486.4	1926.3	984.7
Open shrubs	2885.4	1708.9	942.3
Semidense shrubs	2557.9	2081.0	2172.2
Dense shrubs	317.3	826.2	1047.0
Agricultural land use	1464.9	1092.3	2393.4
Villages and towns	16.8	17.5	34.4
Total	26,466.5	26,466.5	26,466.5

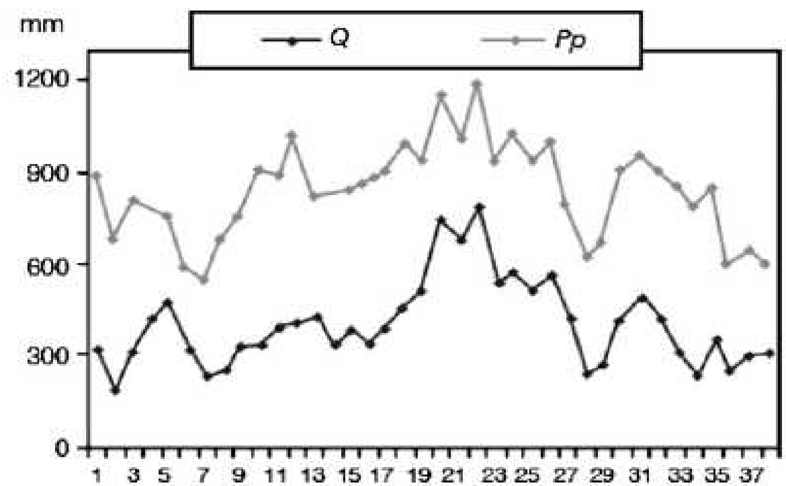


Figure 4 Time series of annual precipitation and streamflow.

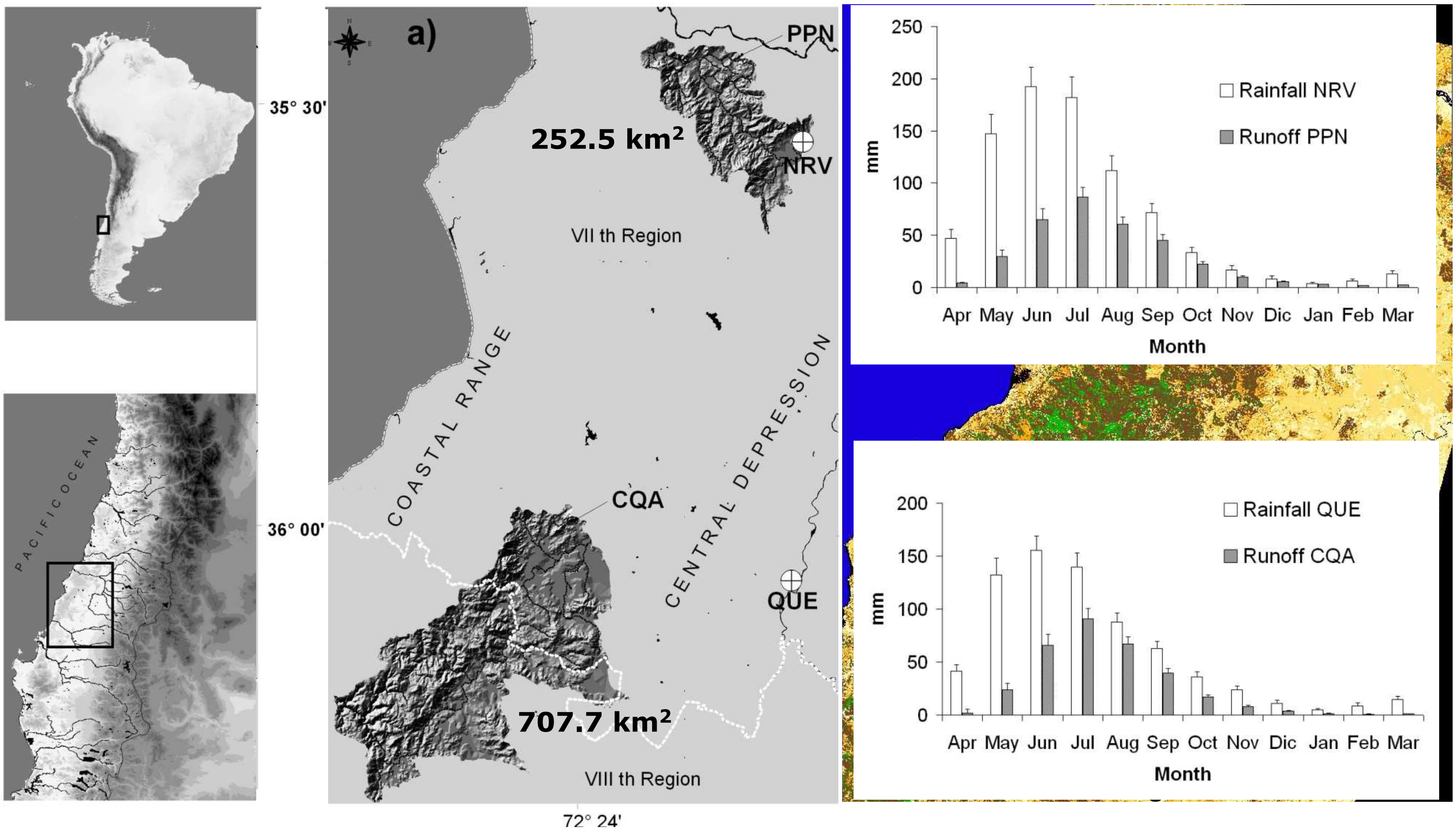
Conclusions

Finally, it is not possible to conclude that *P. radiata* (D. Don) forests in Purapel river basin have generated a decrease of annual and monthly peak flows, and more likely, the results tend to conclude that there are not significant differences in the hydrological behavior of the Maule native forest and the plantations of *P. radiata* (D. Don).

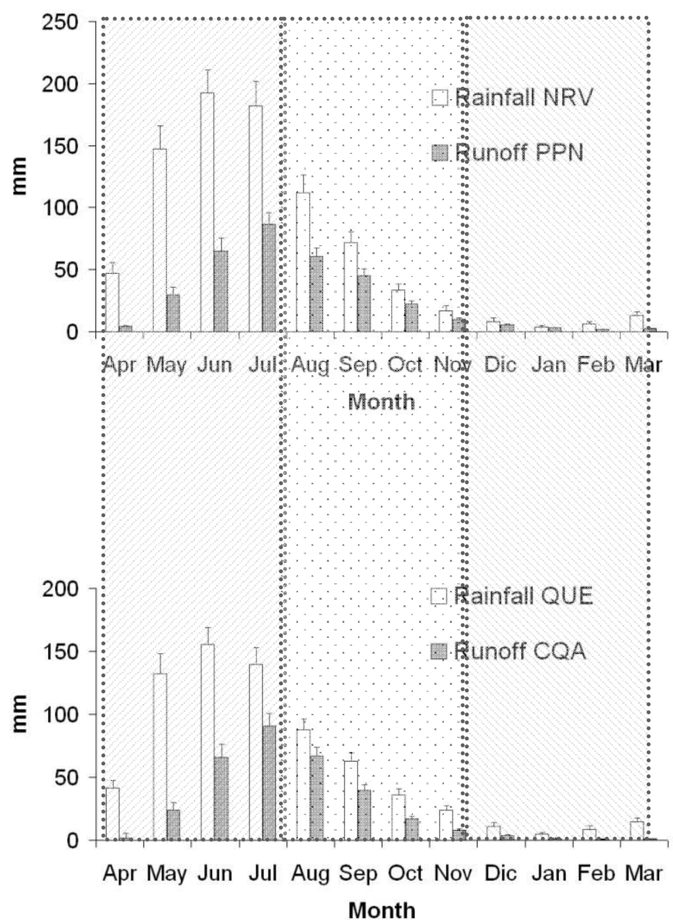
Why?

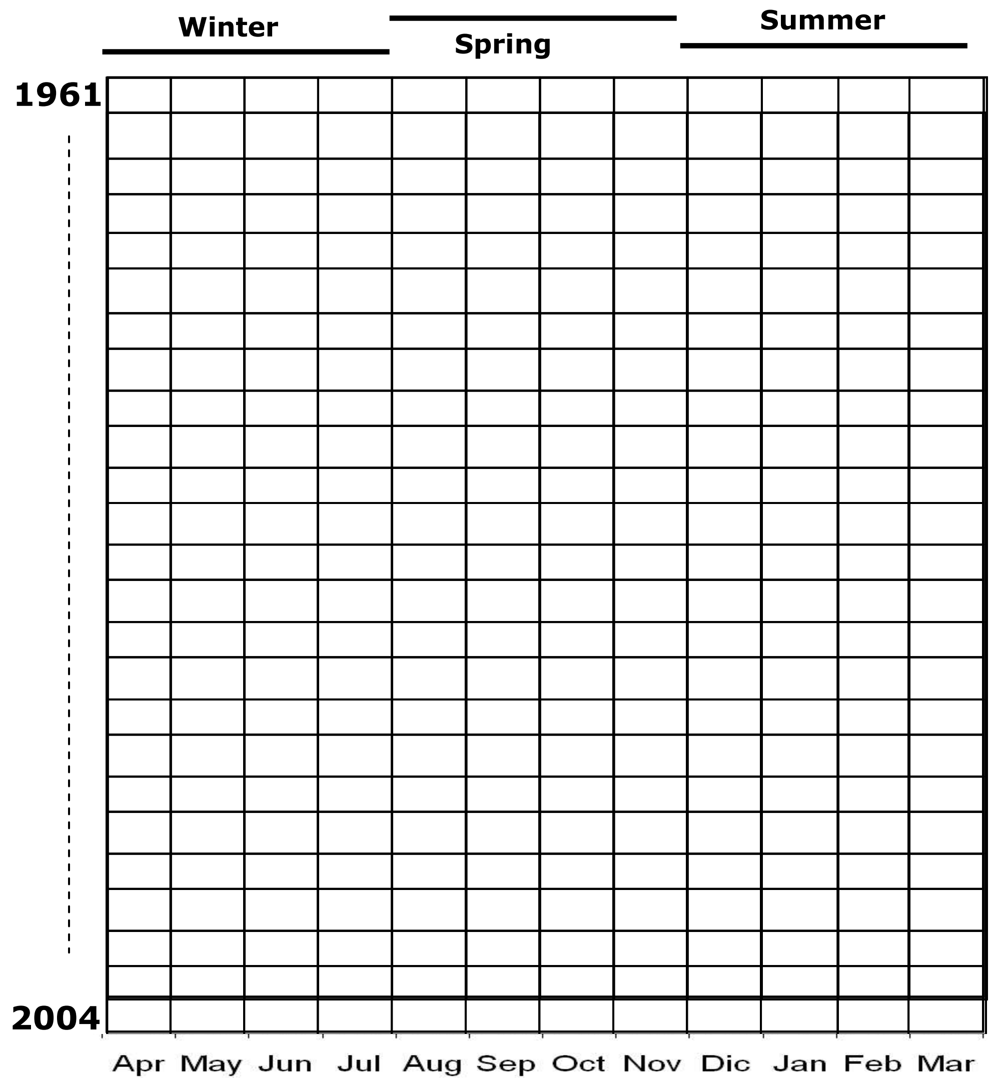
Quantify the change in runoff associated with the conversion of deciduous Nothofagus spp. native forests to exotic *Pinus radiata* plantations in the Coastal Range of South-Central Chile.

Data and methods



Data and methods





FORECOS

Data and methods

$$q_i = \pi(P_i) + \varepsilon_i$$

Linear regression analysis

Ho = Temporal distribution ε_i = 0

HA = Temporal distribution ε_i ≠ 0

$q_i =$ Annual and seasonal streamflow

$\pi(P_i) = (P_i)$ Annual precipitation π Funtion

$\varepsilon_i =$ Ramdom error

* Log tranformation

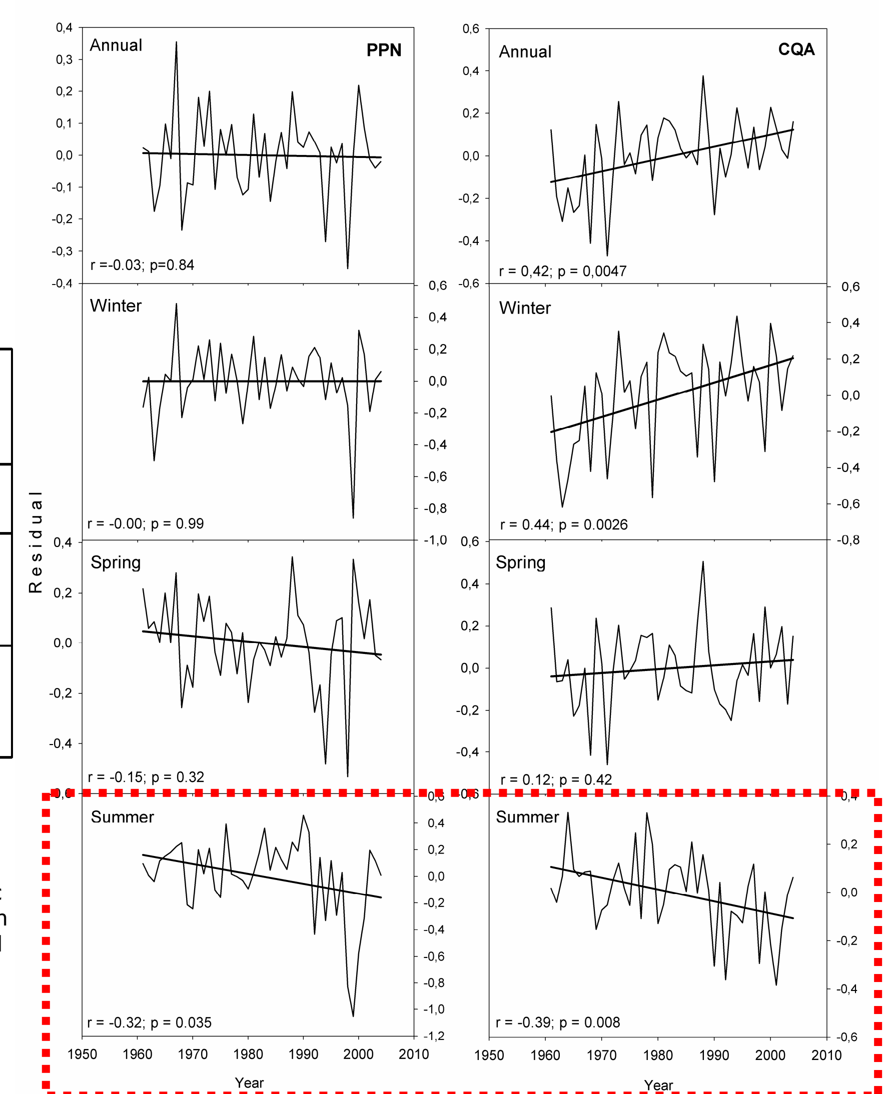
Reconstructed summer runoff for historical period using the least-squares linear equation added a 5-year moving-average smoothed estimation of the runoff residual

Multiple regression model. Precipitation and land-use cover as independent variables (forward stepwise technique)

Results and discussion

$$q_i = \pi(P_i) + \varepsilon_i$$

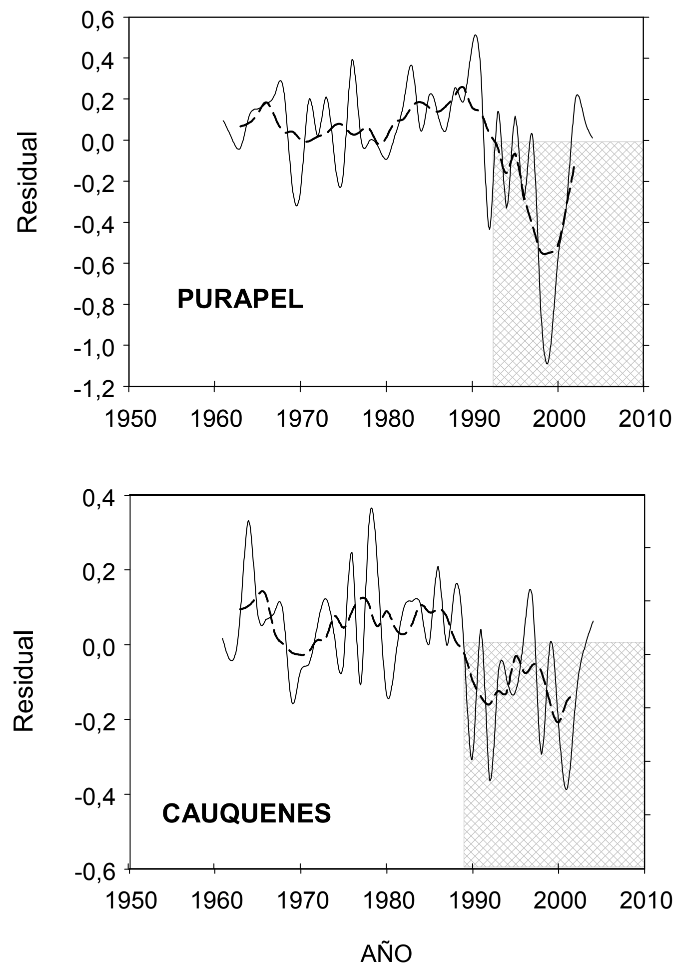
code	Mean precipitation (mm)	Mean runoff (mm)			
	Annual	Annual	Winter	Spring	summer
PPN	874.9 (43.6)	336.6 (28.8)	185.8 (18.9)	138.3 (12.4)	12.5 (1.3)
CQA	753.7 (31.7)	320.7 (26.6)	181.9 (19.6)	131.7 (10.6)	6.9 (0.5)



Annual precipitation (dashed lines) related to annual and seasonal streamflow (solid lines) variability for PPN and CQA watersheds during 1961–2004. Pearson's coefficient of correlation (r) between annual precipitation (logarithmic unit) and annual and seasonal streamflow (logarithmic unit) for PPN and CQA (n = 44). All r coefficients are significant p < 0.001. Z values represent a standard score considering a normal distribution of the value, with mean cero and variance 1 (Zar, 1999).

Results and discussion

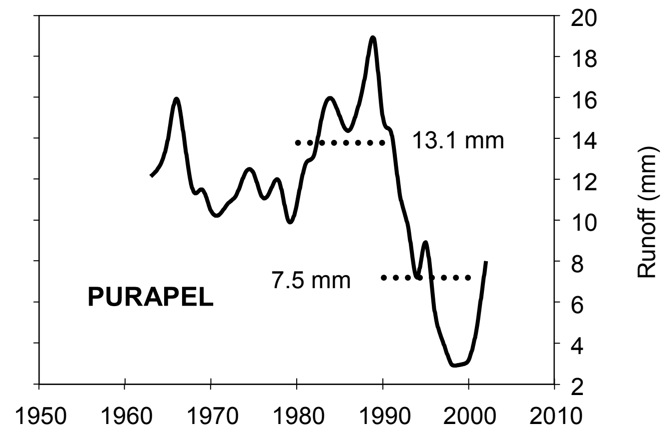
$$q_i = \pi(P_i) + \varepsilon_i$$



Results and discussion

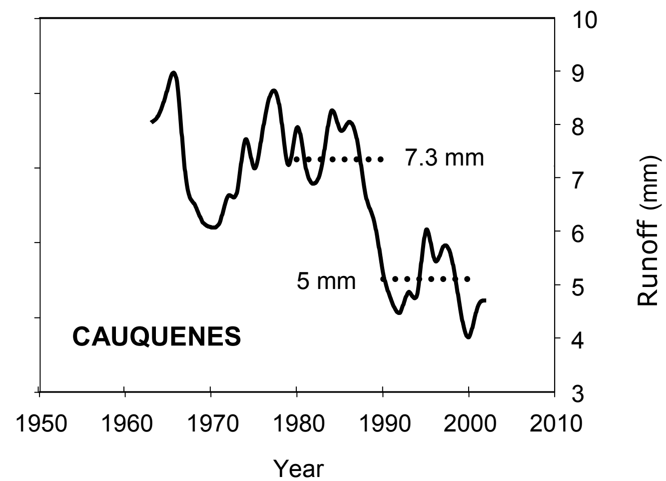
$$q_i = -3.92 + 1.68\, P_i + \varepsilon_i$$

42.7%

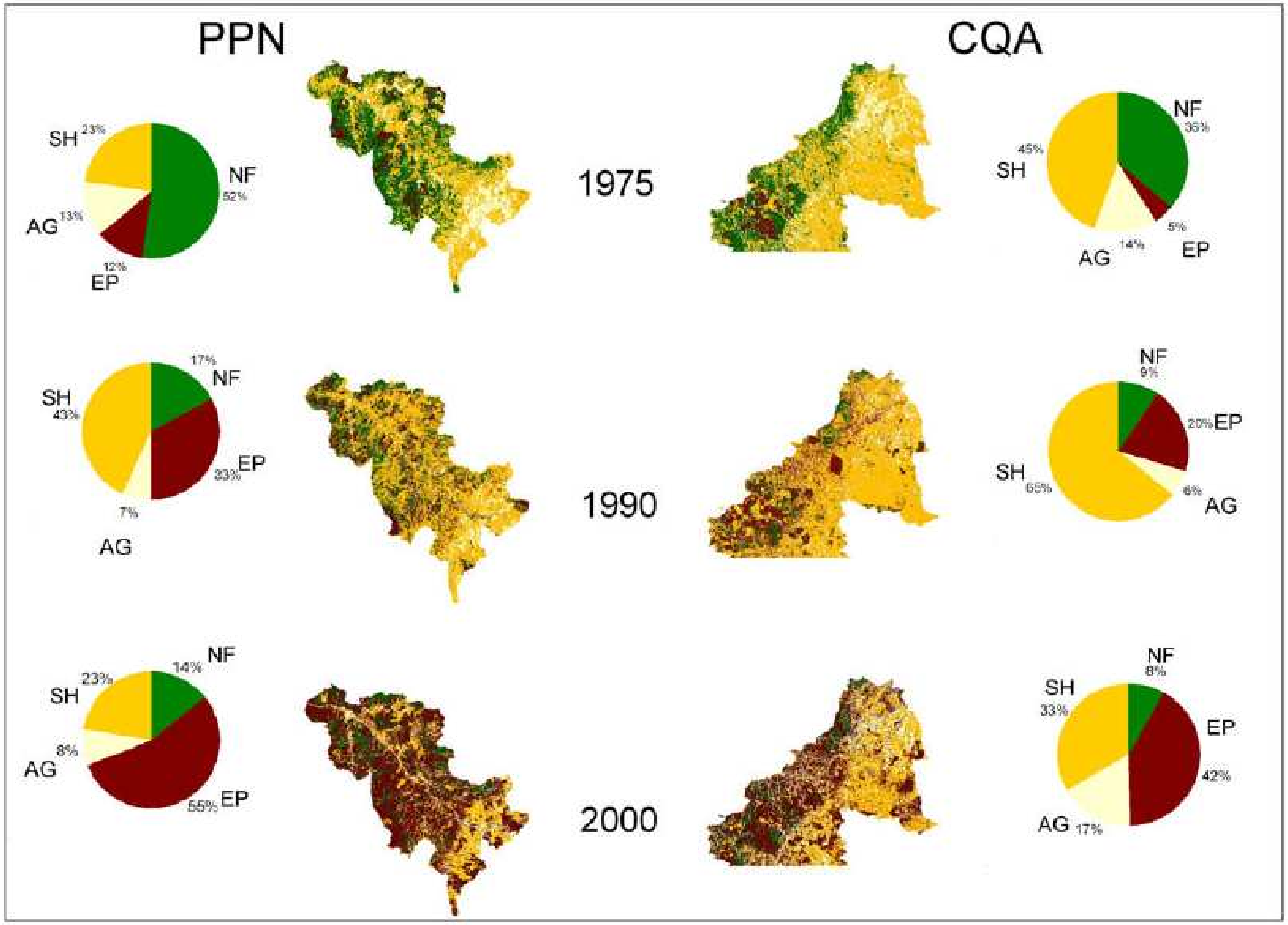


$$q_i = -3.62 + 1.42\, P_i + \varepsilon_i$$

31.9%



Results and discussion



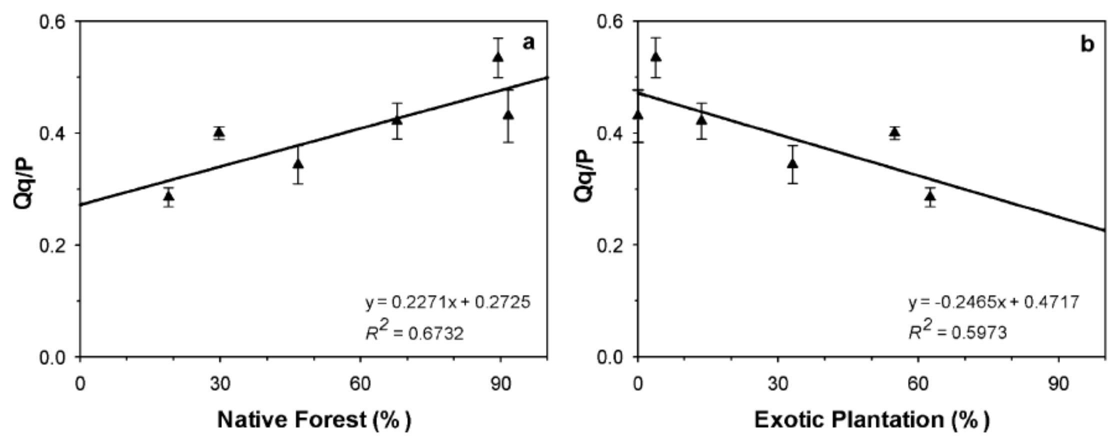
NF: Native forest
EP: Forest exotic plantation (including young plantation and recent clearcuts)
AG: Agriculture and pasture land
SH: Shrubland

Results and discussion

Beta coefficients, adjusted coefficient of multiple regression (R^2_{adj}), Fisher (*F*) and probability (*P*) values of the multiple regression models among the different runoff as a function of precipitation and the land cover categories, in PPN and CQA watersheds.

Log runoff	Log annual pp	Native forest (%)	Exotic tree plantation (%)	Agriculture and pasture land (%)	Shrubland (%)	R^2 (adj.)	*F*	*p*
PPN								
Annual	0.94*	–	–	–	–	0.87	$F_{1,13} = 94.8$	0.0000
Winter	0.83*	–	−0.19	–	–	0.69	$F_{2,12} = 16.9$	0.0003
Spring	0.79*	–	–	–	–	0.59	$F_{1,13} = 21.3$	0.0004
Summer	0.52*	–	−0.45*	–	–	0.42	$F_{2,12} = 5.92$	0.0153
CQA								
Annual	0.85*	–	–	–	–	0.69	$F_{1,13} = 32.9$	0.0000
Winter	0.78*	–	–	–	–	0.58	$F_{1,13} = 20.1$	0.0006
Spring	0.72*	–	–	–	–	0.49	$F_{1,13} = 14.5$	0.0022
Summer	0.59*	–	−0.44*	–	–	0.49	$F_{2,12} = 8.03$	0.0061

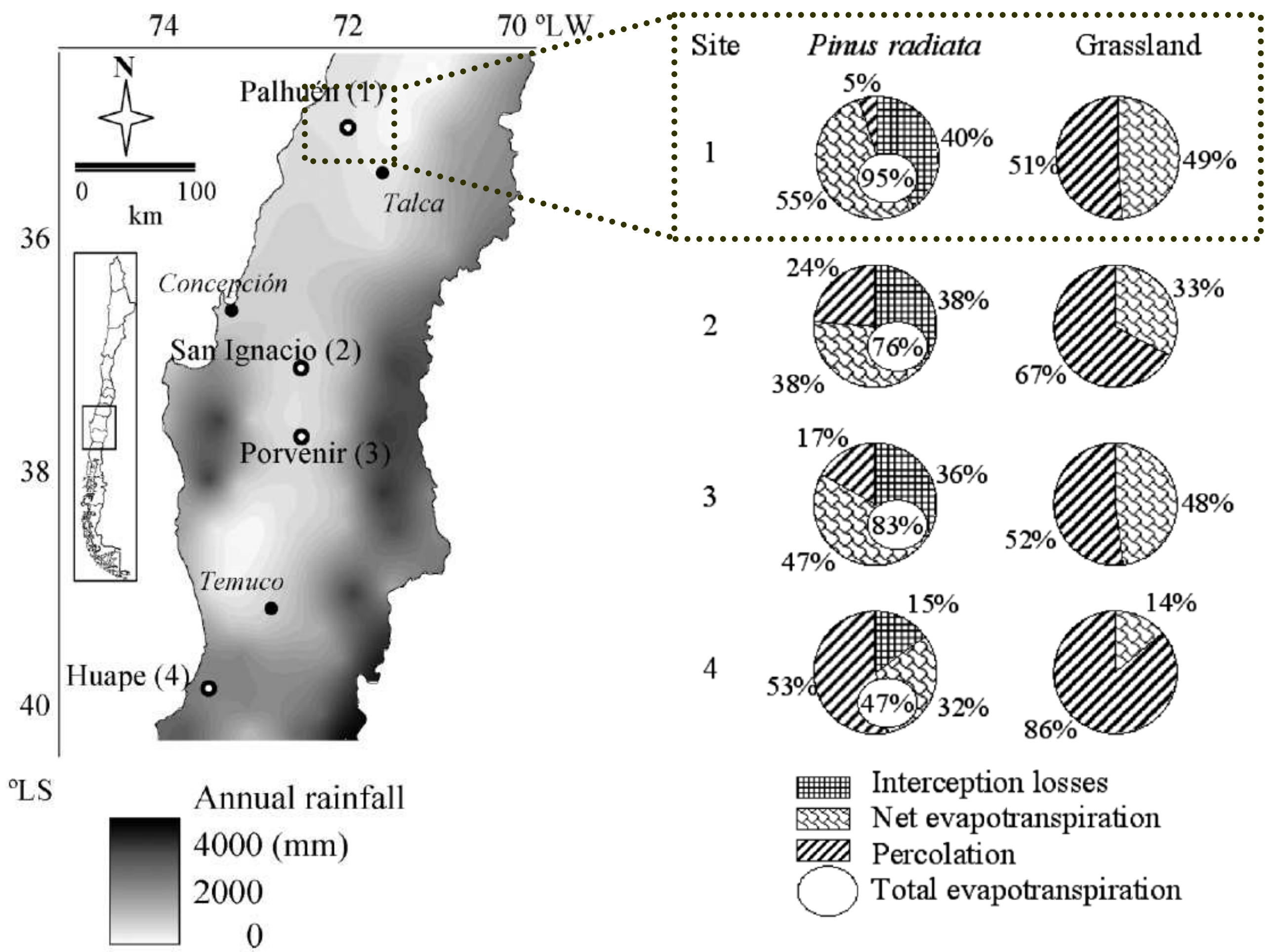
* Parameters that turned out to be statistically significant in the model with $p < 0.05$.



A. Lara et al. / Forest Ecology and Management 258 (2009) 415–424

Results and discussion

HYDROLOGICAL PROCESSES
Hydrol. Process. 22, 142–148 (2008)
Published online 29 May 2007 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/hyp.6582



Summary

- Contribution to understanding of streamflow variability and to the identification of natural and human-induced forcing in runoff for large watersheds (i.e. >100 km^2)
- Streamflow production is a function of land use change. Decrease in summer runoff is associated with *Pinus radiata* forest exotic plantation land cover
- In addition to land-use change as an explanation of runoff variation, alternative hypotheses should be considered. Future studies might assess the potential influence of geomorphology factors, temperature variations and its evaporative effect, and changes in storm intensities. Other hypotheses should test the effects of land-use spatial patterns, stand age and density, as well forest management schemes (i.e. silvicultural treatments, rotation period, clearcut size).

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