# Integration of 3-PG into SWAT to Simulate Growth of Evergreen Forests in Australia

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# Introduction

Extensive land use changes are expected to occur across much of Australia in the coming decades

Land use change on a large scale will have significant impacts on catchment water yield and water quality

Urgent need for tools that can predict impacts of impending land use change

SWAT is becoming increasingly popular in Australia because few models have been developed to date that have the same capabilities for land use change studies

# Introduction

SWAT was applied to the Woady Yaloak River catchment in southern Australia

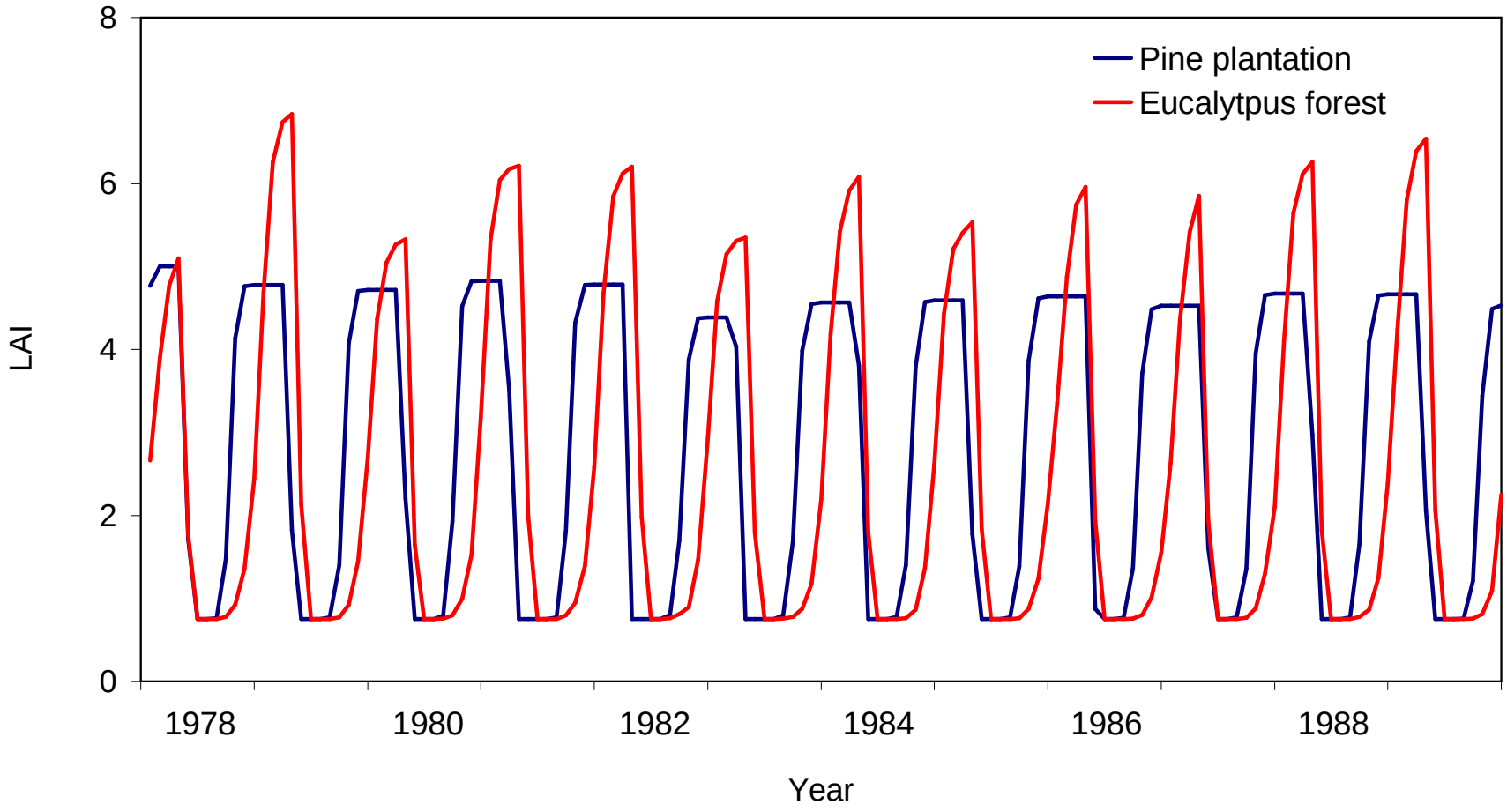
A deficiency was identified with the plant growth model incorporated in SWAT

Annual and seasonal trends of simulated LAI and biomass were unrealistic for eucalyptus forests and pine plantations

Long-term trend in LAI was not reproduced accurately for either forest type

Several SWAT users in Australia and overseas have reported identical problem

# Introduction



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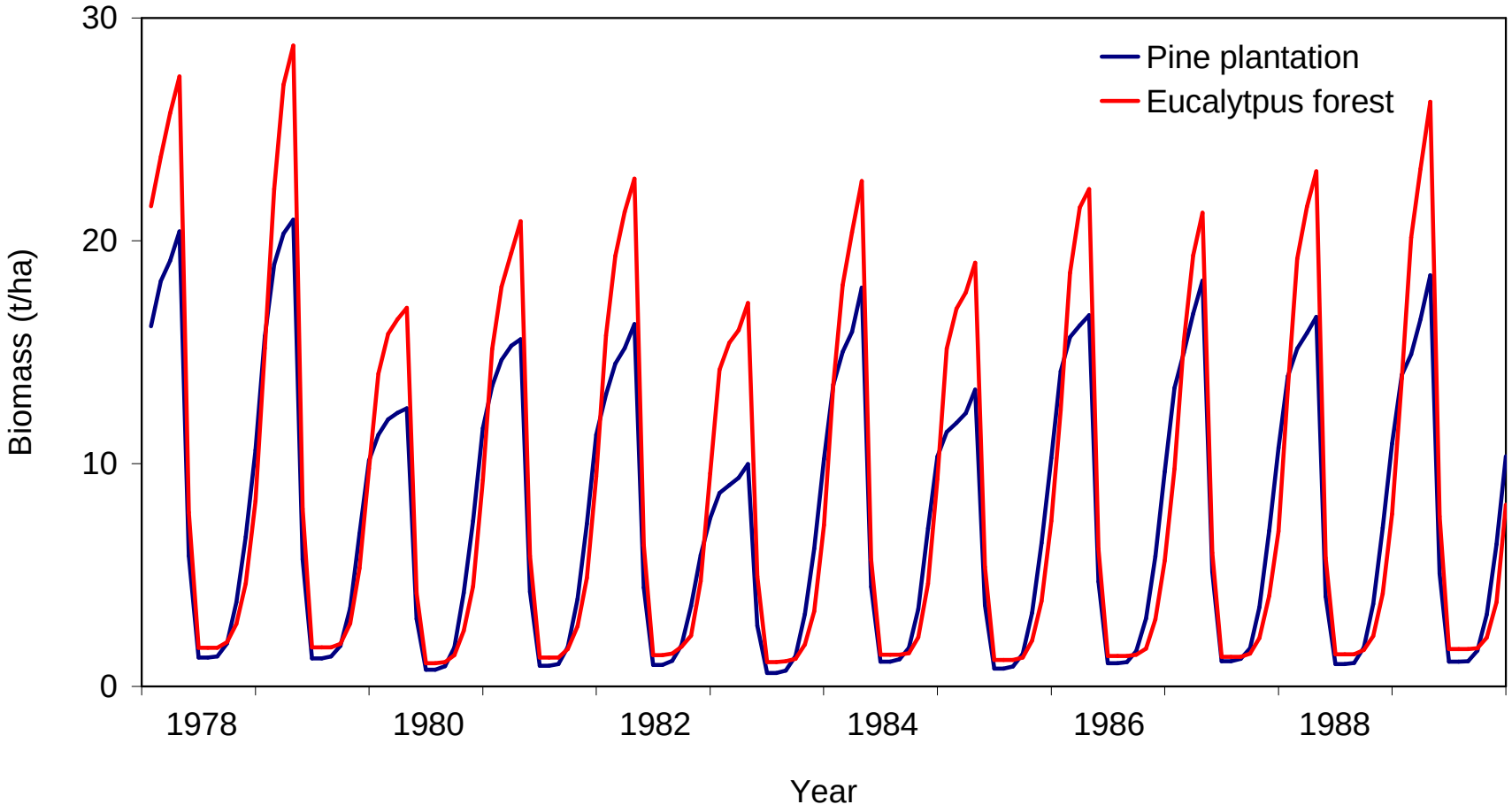

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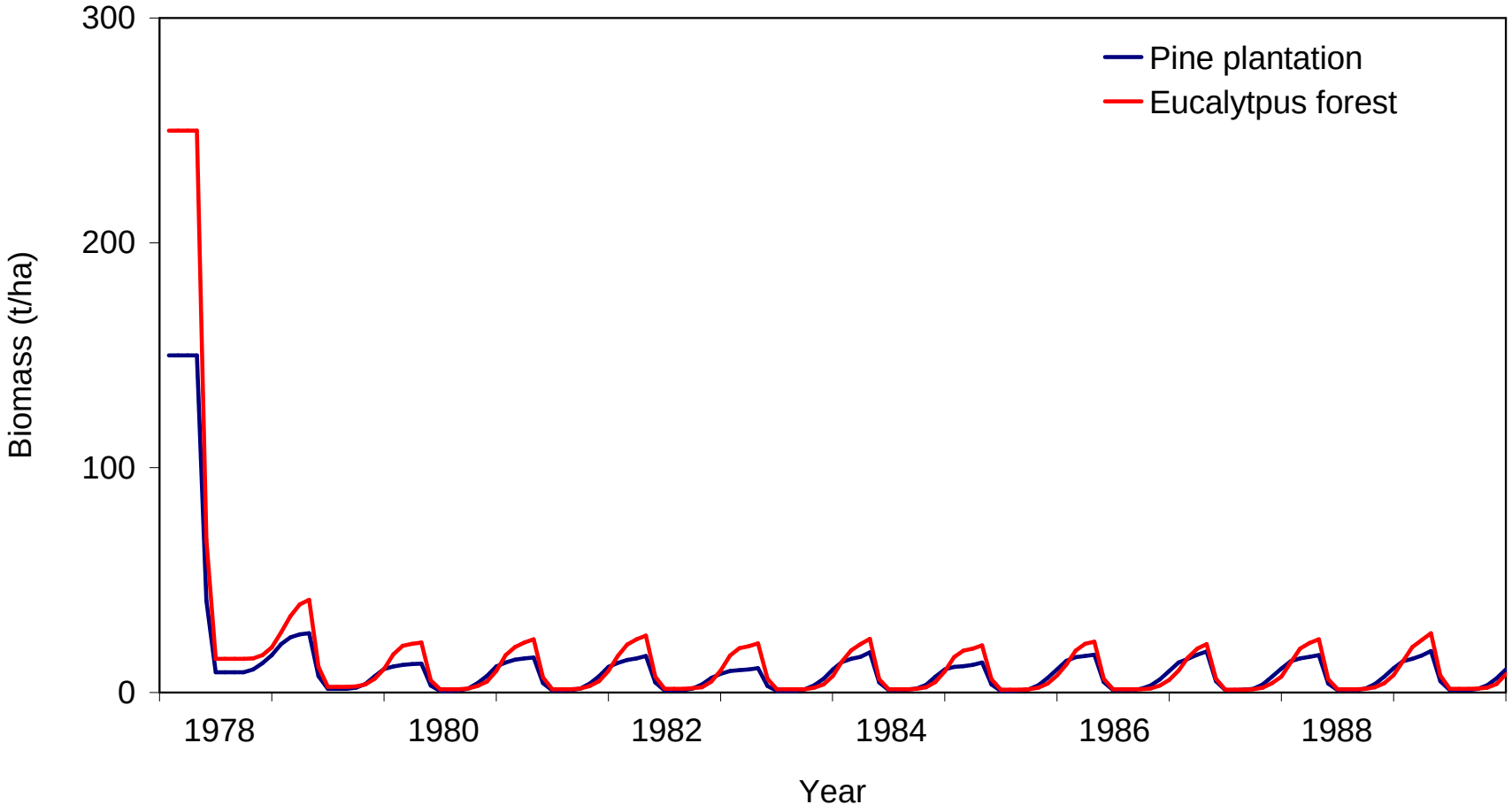


# Introduction

Cause of fluctuations attributed to model forcing all species of trees to go dormant and lose their leaves in response to shortened daylength

Eucalypt and pine trees are evergreen species in Australia and do not enter a prolonged dormant period or lose their leaves at the onset of winter

Dormancy mechanism was deactivated in SWAT

Seasonal fluctuations were not as pronounced

Long-term trend for LAI still not reproduced adequately

# Introduction

SWAT utilises a single plant growth model to simulate the growth of all vegetation

Simplified version of the EPIC plant growth model, which is parameterised and utilised principally for agricultural crops

No significant differences in the way in which forest growth and crop growth are simulated by SWAT

Forest growth is differentiated from crop growth by utilising a different set of values for the model parameters

# Introduction

Realistic characterisation of LAI is very important in studies that endeavour to predict the impacts of land use change on water yield

Interception and transpiration are key processes that are dependant on LAI

The inability of SWAT to simulate LAI of evergreen forests has major implications for application of the model in Australia

A soundly based forest growth model, 3-PG, was integrated into SWAT to improve prediction of LAI and biomass for evergreen forests

# 3-PG

3-PG – Physiological Principles in Predicting Growth

Dynamic, process-based model of forest growth that predicts the net photosynthesis by forest stands on a monthly basis

Utilises simple relationships derived from research that allows process-based calculations to estimate forest growth in terms of a few variables

Generalized stand model applicable to plantations and even-aged, relatively homogenous forests

Model parameters related to tree physiology and derived from field measurements

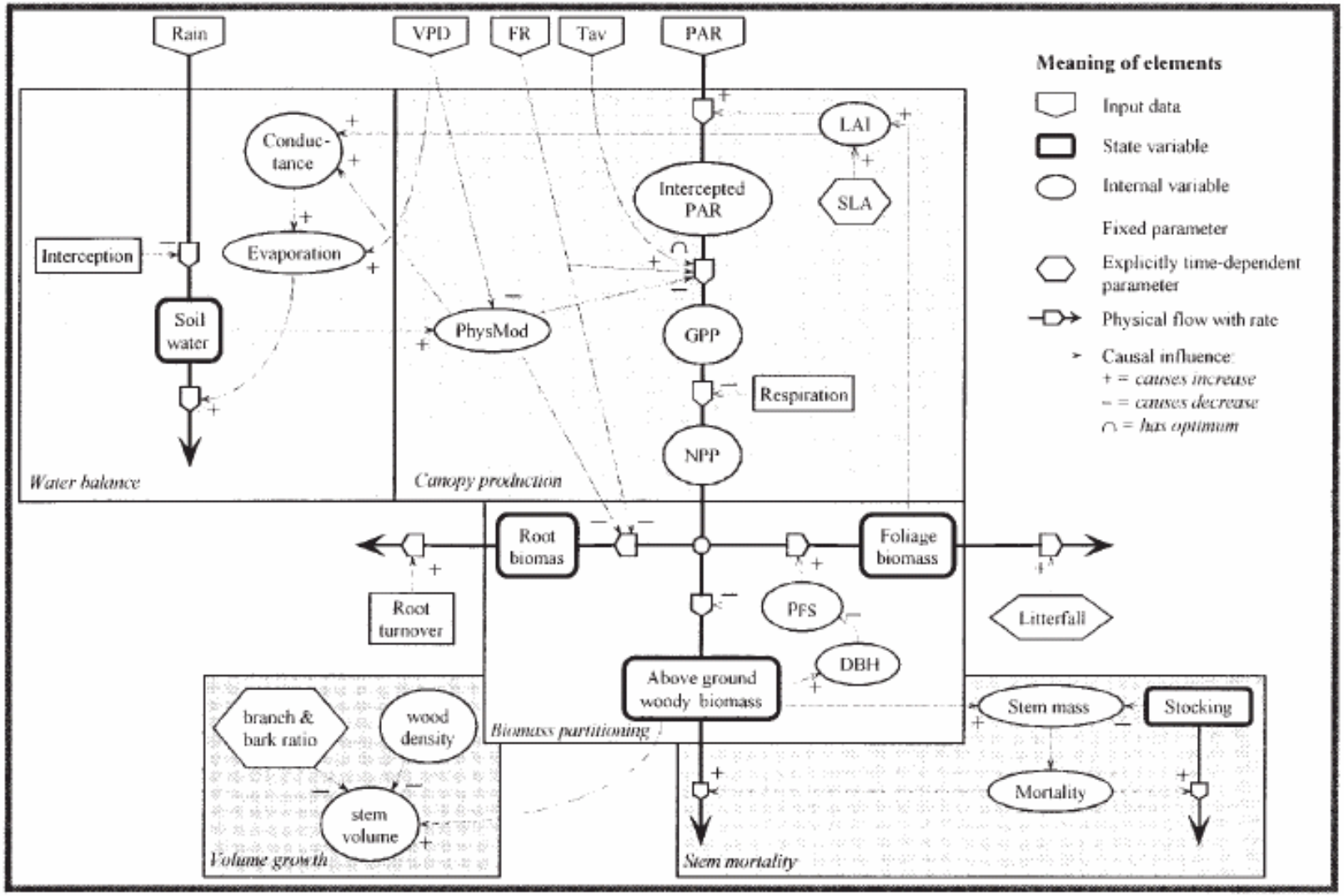
# 3-PG

Most process-based models have limited practical value because they are too complex and are over-parameterised

3-PG less complex than most other process-based models, yet is soundly based on a number of well-established physiological principles

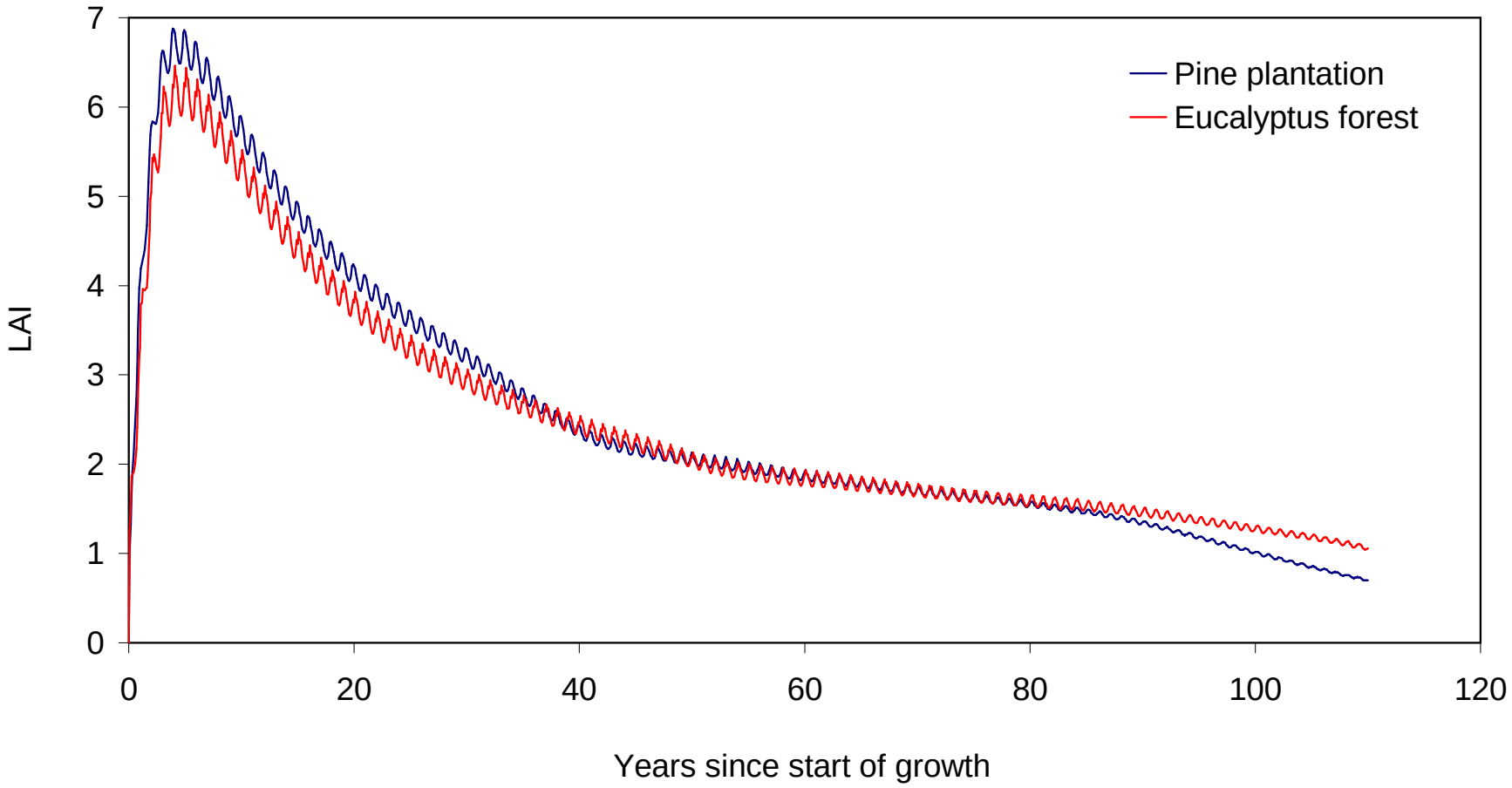
3-PG has been widely tested in Australia, USA, Canada, China, Brazil, South Africa and U.K.

# 3-PG




Source: Kirschbaum et al. (2001)

# 3-PG


LAI
7
6
5
4
3
2
1
0
0
20
40
60
80
100
120
Years since start of growth
Pine plantation
Eucalyptus forest

# Integration of 3-PG into SWAT

3-PG source code converted from Visual Basic to Fortan90 and incorporated into SWAT as a separate subroutine

SWAT operated on daily time-step while 3-PG operated on monthly time-step

LAI and biomass calculated on first day of every month using 3-PG subroutine

Values held constant for the remainder of the month

Soil water modifier computed using the average soil water content of the previous month as calculated by SWAT

# Study Area

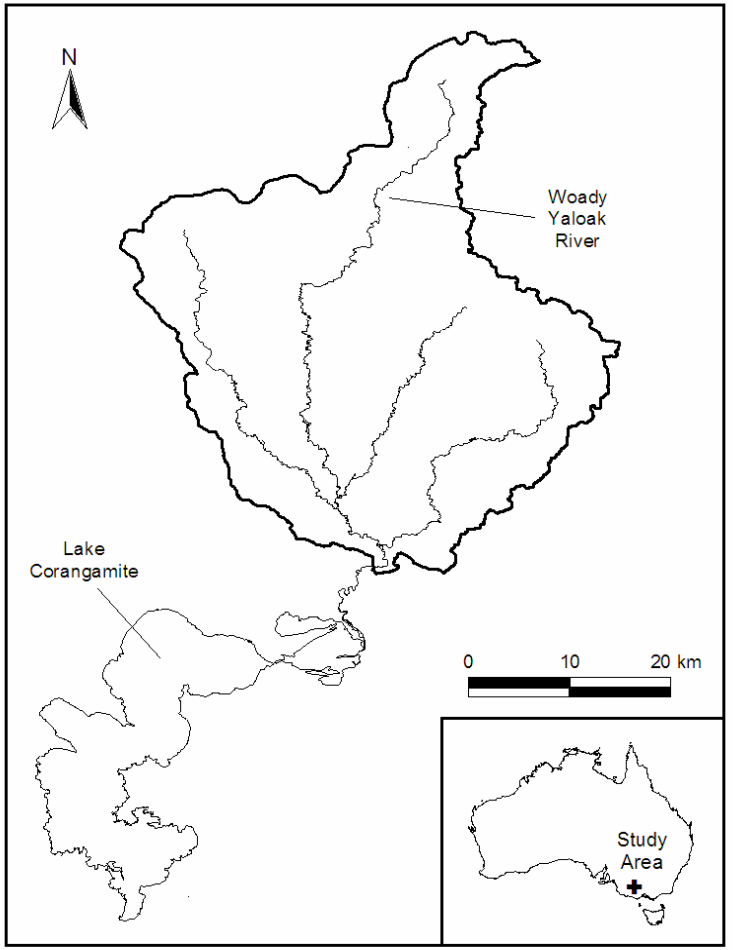
Woady Yaloak River catchment (1157 km$^2$)

Eucalyptus forests and pine plantations occupy approximately 30% of the total area

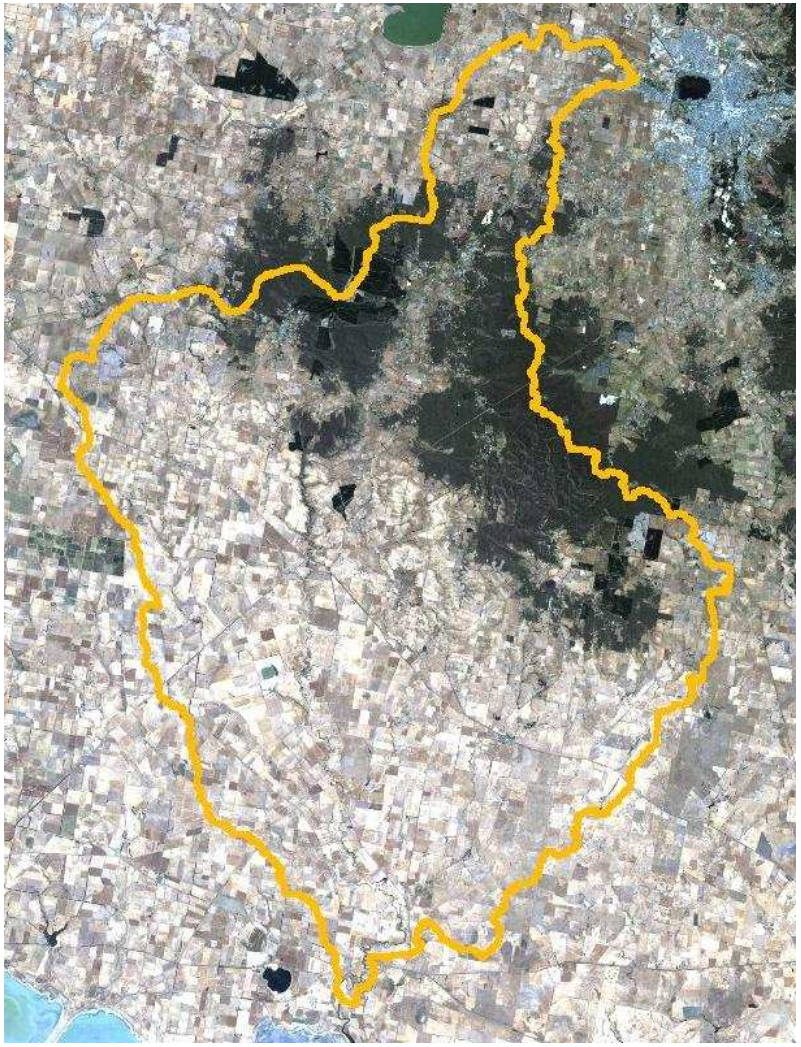
Blue gum plantations being established across the catchment at a steady rate

Harvesting of pine plantations has commenced

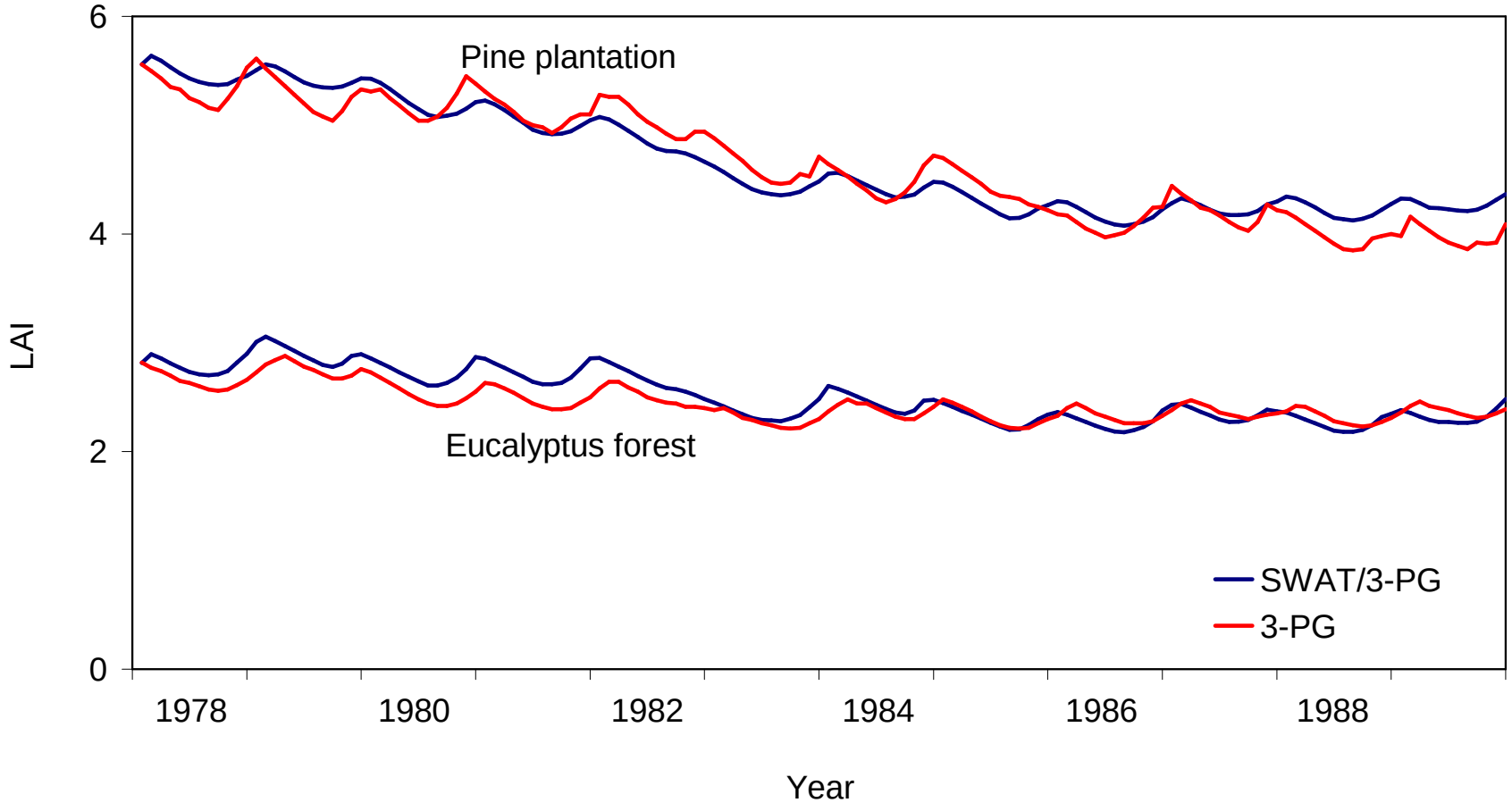
Forests and plantations play an important role in the water balance of the catchment



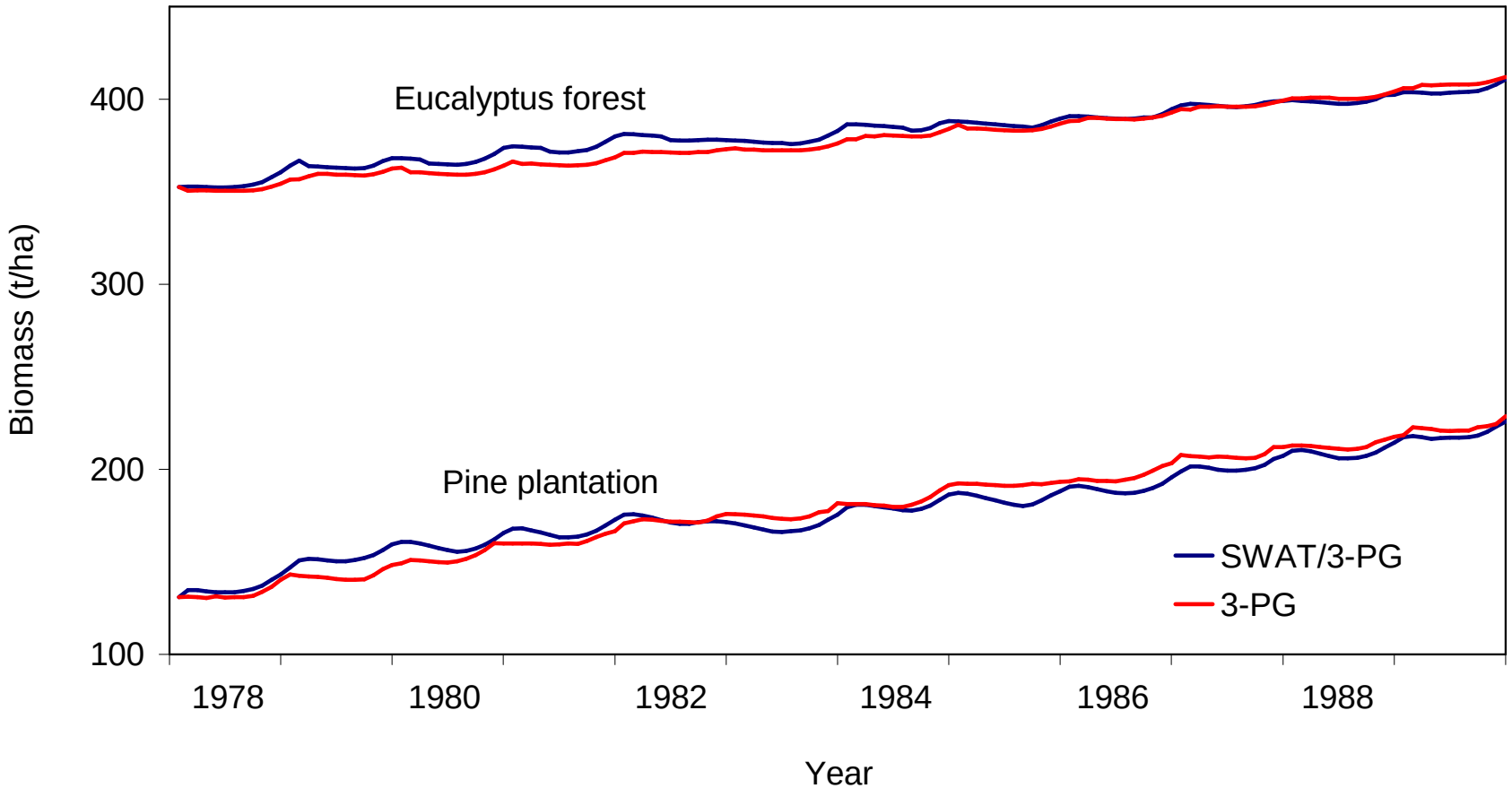
# Study Area



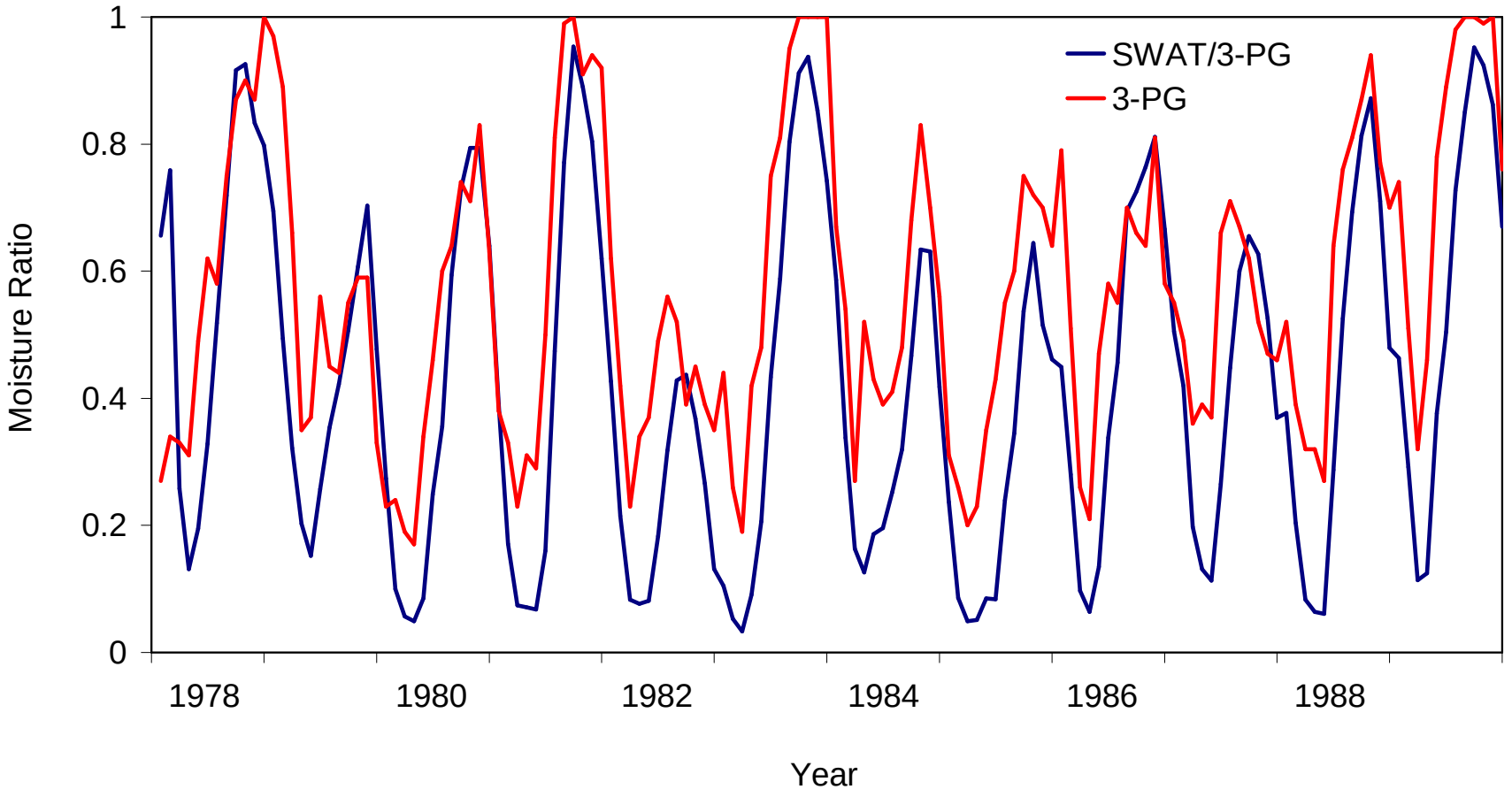
# Results


6
4
2
0
LAI
Pine plantation
Eucalyptus forest
SWAT/3-PG
3-PG
1978
1980
1982
1984
1986
1988
Year

# Results


Eucalyptus forest
Pine plantation
SWAT/3-PG
3-PG
Biomass (t/ha)
400
300
200
100
1978
1980
1982
1984
1986
1988
Year

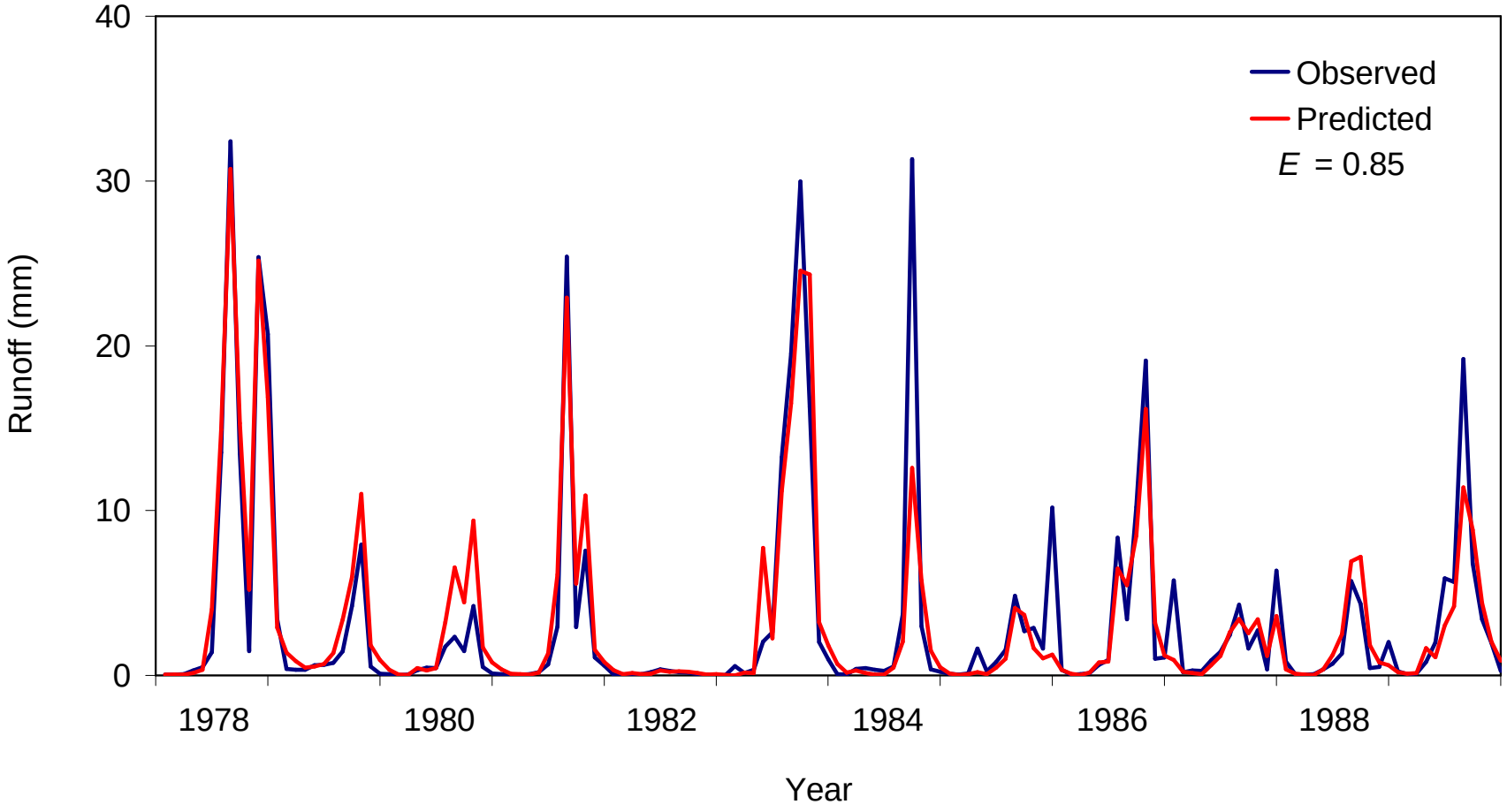
# Results


SWAT/3-PG
3-PG
Moisture Ratio
1
0.8
0.6
0.4
0.2
0
1978
1980
1982
1984
1986
1988
Year

# Results


150
100
50
0
Runoff (mm)
1978
1980
1982
1984
1986
1988
Year
Observed
Predicted
E = 0.90

# Results


Observed
Predicted
E = 0.85
Runoff (mm)
Year
0
10
20
30
40
1978
1980
1982
1984
1986
1988

# Results

| | Calibration | |
|---|---|---|
| **Time step** | **SWAT/3-PG** | **SWAT** |
| Annual | 0.90 | 0.90 |
| Monthly | 0.85 | 0.75 |
| Daily | 0.56 | 0.52 |

# Results

| | Calibration | | Validation | |
|---|---|---|---|---|
| **Time step** | **SWAT/3-PG** | **SWAT** | **SWAT/3-PG** | **SWAT** |
| Annual | 0.90 | 0.90 | 0.92 | 0.90 |
| Monthly | 0.85 | 0.75 | 0.84 | 0.85 |
| Daily | 0.56 | 0.52 | 0.46 | 0.51 |

# Conclusions

Original version of SWAT cannot simulate LAI and biomass of eucalyptus forests and pine plantations accurately

3-PG was integrated into SWAT to overcome this deficiency

LAI and biomass of evergreen forests predicted more accurately by SWAT/3-PG

Results of this study are promising and warrant further research be carried out to test SWAT/3-PG more stringently

In general, more attention should be focused on improving the prediction of forest growth by SWAT

# Acknowledgements

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Geoff Podger (CRC for Catchment Hydrology)

Website for 3-PG – www.ffp.csiro.au/fap/3pg

# References

Kirschbaum, M.U.F., Carter, J.O., Grace, P.R., Keating, B.A., Keenan, R.J., Landsberg, J.J., McKeon, G.M., Moore, A.D., Paul, K.I., Pepper, D..A, Probert, M.E., Richards, G.P., Sands P.J. and Skjemstad, J.O. (2001). Brief description of several models for simulating net ecosystem exchange in Australia. In: M.U.F. Kirschbaum & R. Mueller (Eds.), Net Ecosystem Exchange, CRC for Greenhouse Accounting, Canberra, 8–29.