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Evapotranspiration partitioning and water use patterns in a sub-tropical evergreen forest in southern China

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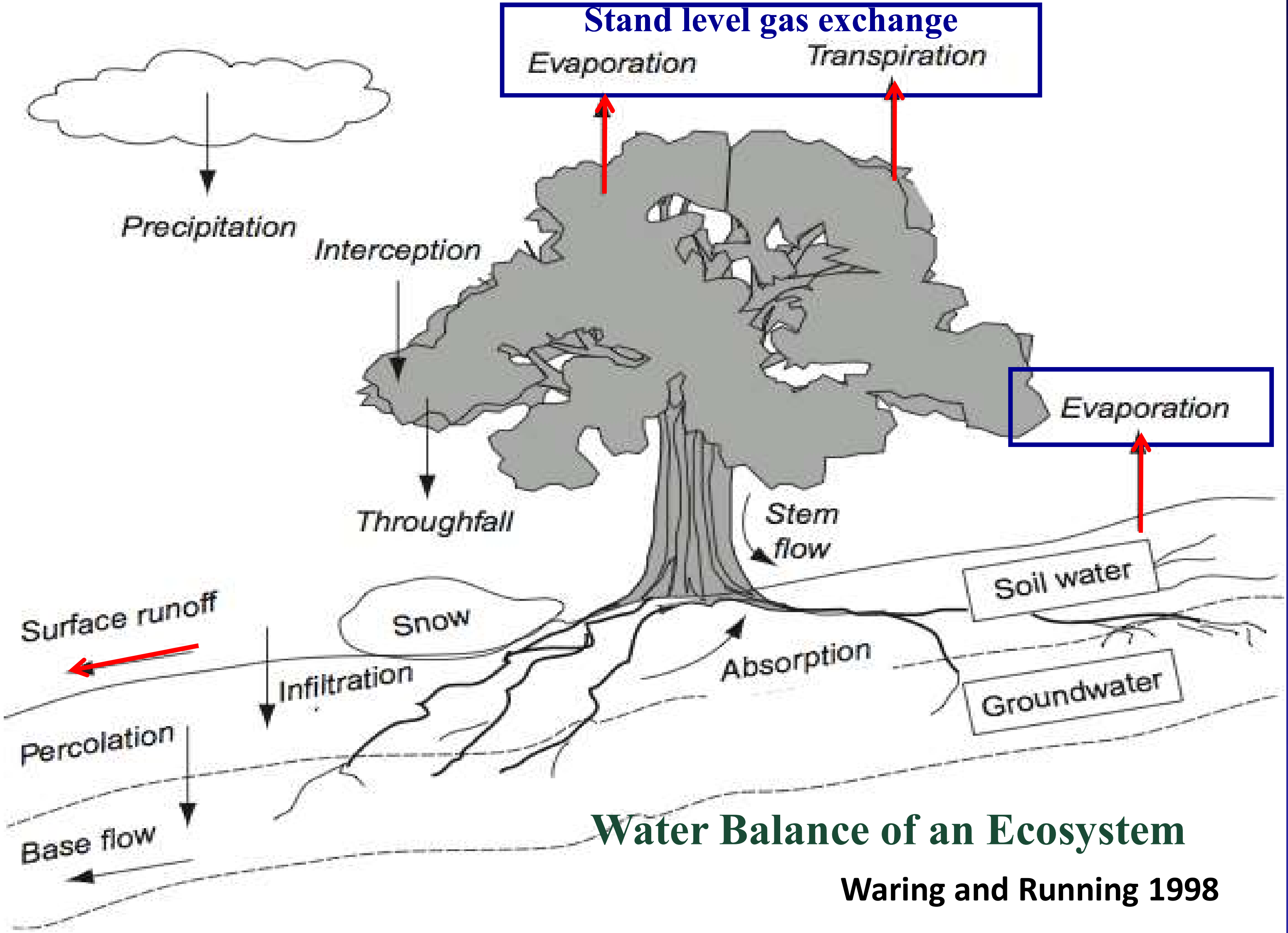
Presentation Outline

1. Background and site description
2. Research Goals
3. Data Analysis & Results
4. Summary

1.1 Background



Water Balance of an Ecosystem

Waring and Running 1998

1.1 Background

Ecosystem evapotranspiration (ET) includes transpiration and evaporation, however, the contributions of the two components to total ET are highly variable in different ecosystem type or even successional stage. Many studies indicates that transpiration is the dominant component of ET across a variety of ecosystems

Leuning et al., 1994; Wilson et al. 2001; Williams et al. 2004

1.1 Background

<u>How much water is used by forests in Dinghushan catchment?</u>

Different Elevation and Aspect

Different Forest Structure

Different Meteorological Condition

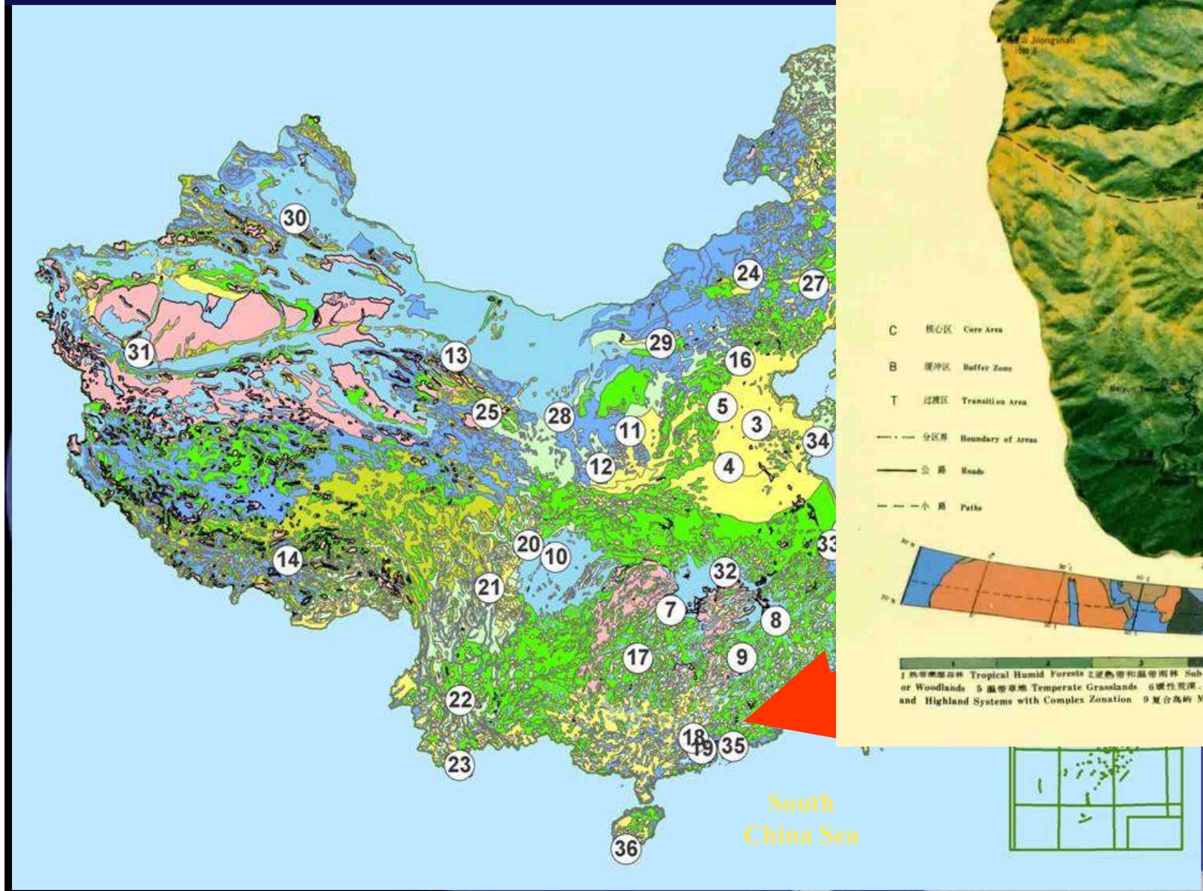
Different Species Composition

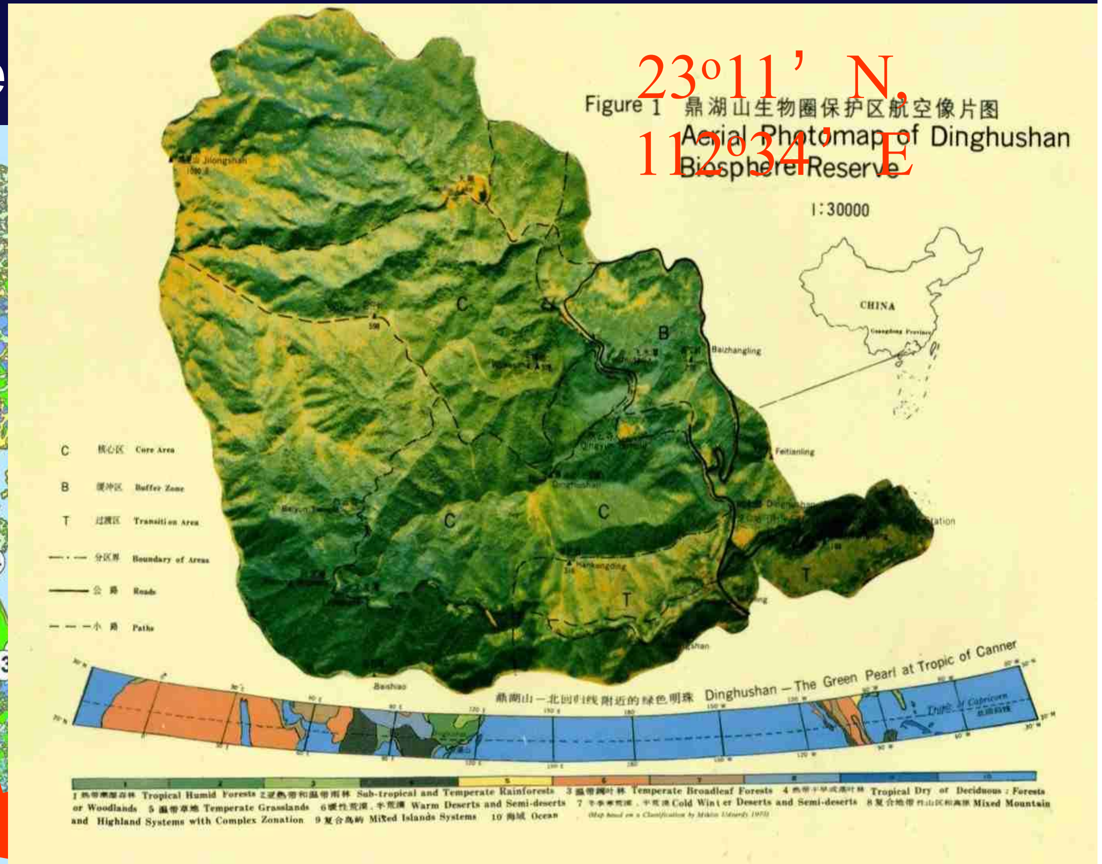
Different On/Off Set

➔ Estimate Stand Transpiration!

1.2 Site descriptions

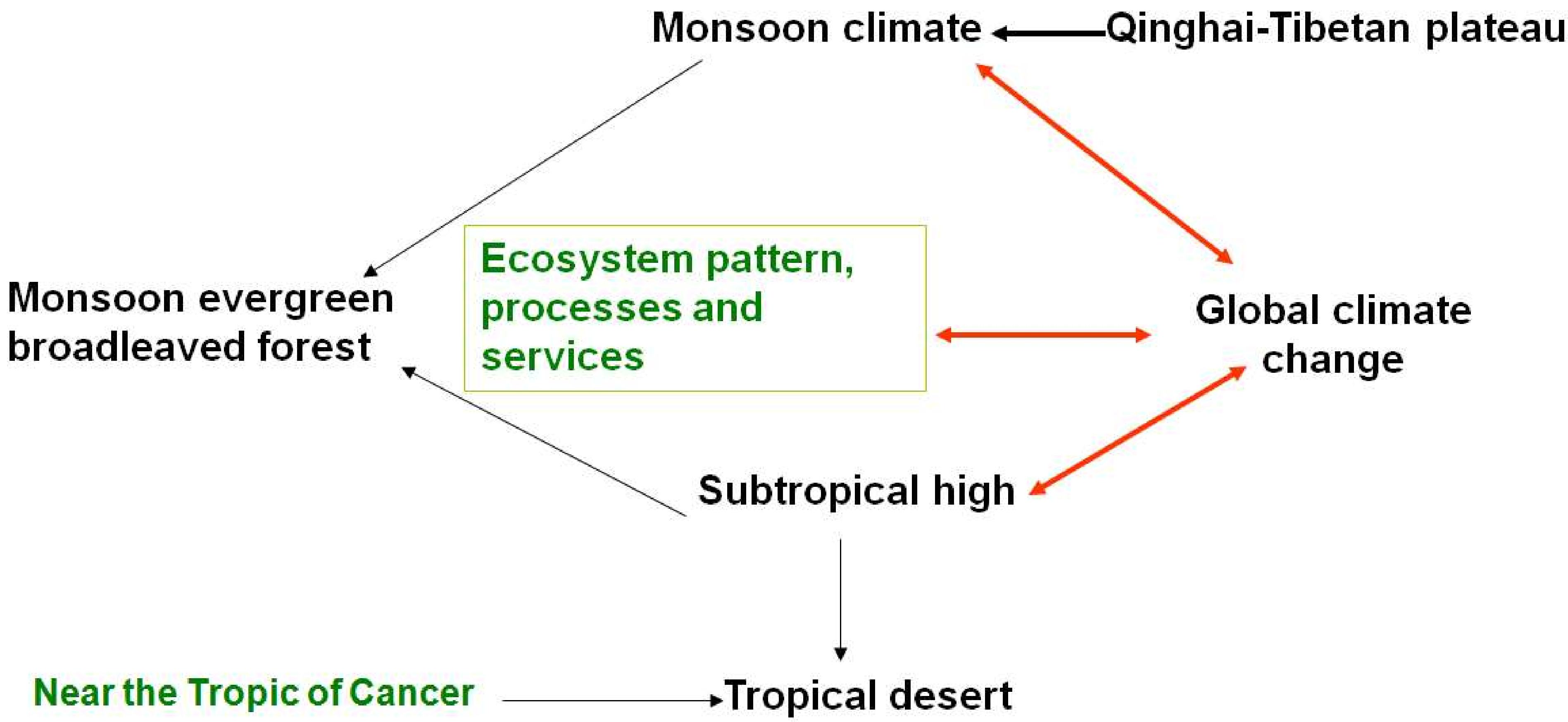
Dinghushan-The Green Pe



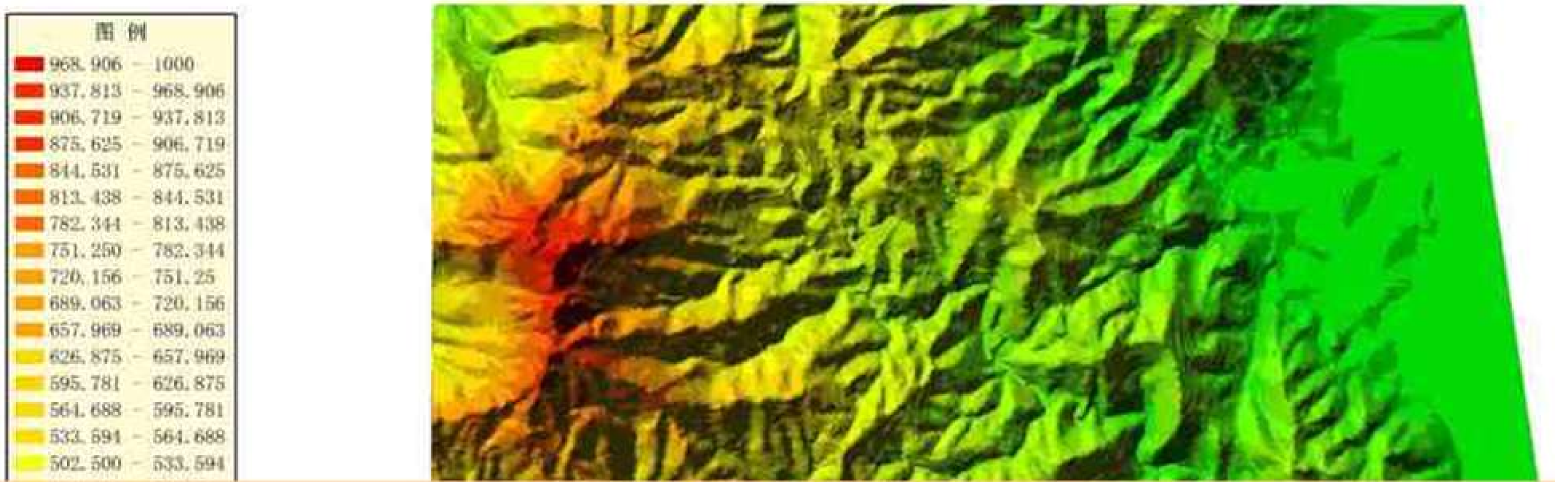


Global vegetation map (source: NASA)

Excellent venue for ecosystem research



Map of 3D Topography of Dinghu Mountain Research Station of Forest Ecosystem



Area： 1,133 ha

Elevation: ranging from 10 to 1,000 m above sea level

Climate: typical south subtropical monsoon climate

Annual average precipitation: 1,950 mm

Annual mean temperature: 20.8°C

Relative humidity: 80%

Predominant soil types: lateritic red-earth (in the lower altitude region) and yellow earth (in the higher altitude region)

1956: Dinghushan Natural Reserve was established

1978: Dinghushan Forest Ecosystem Research Station was established

1979: DNR became the NO.17 research station in UNESCO's MAB Network

1991: DHS joined in Chinese Ecosystem Research Network (CERN), CAS

1999: DHS joined in National Field Research Station (pilot station)

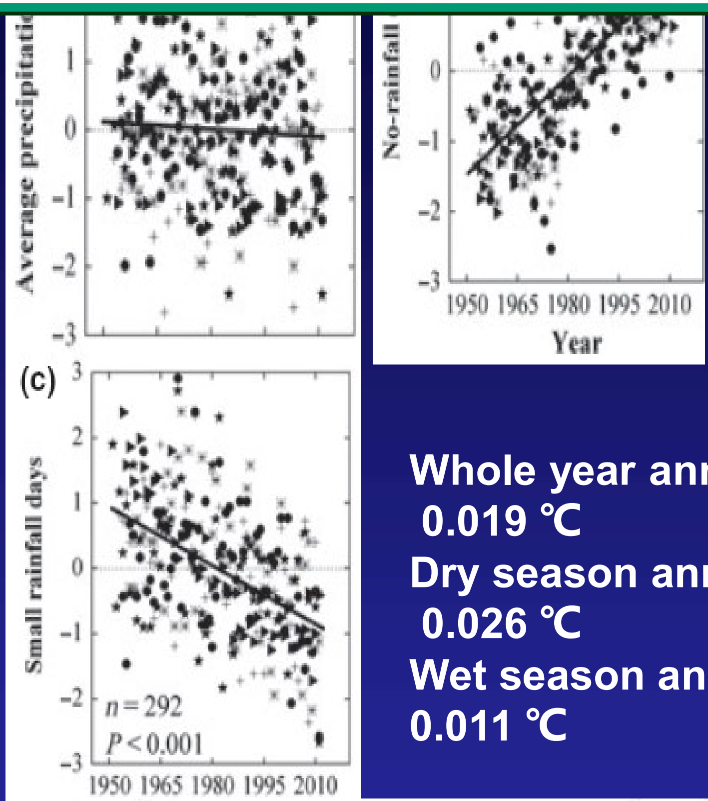
2002: DHS became a research station in China Fluxnet, CAS

2003: DHS joined in the Regional Atmospheric Observation Network, CAS.

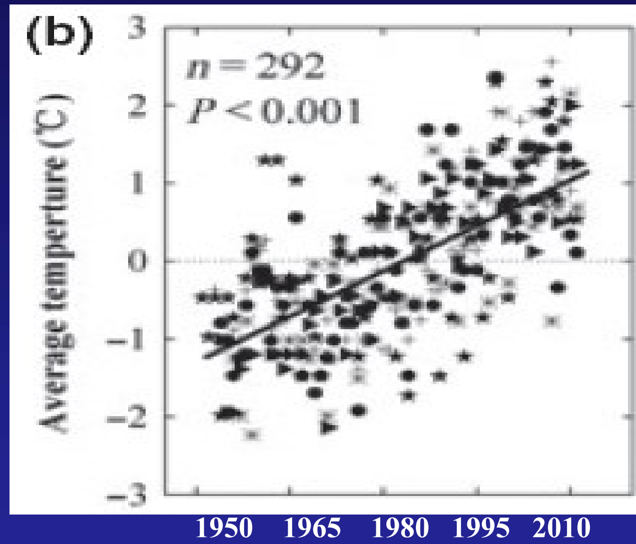
2007: DHS was selected as regional core station in CERN

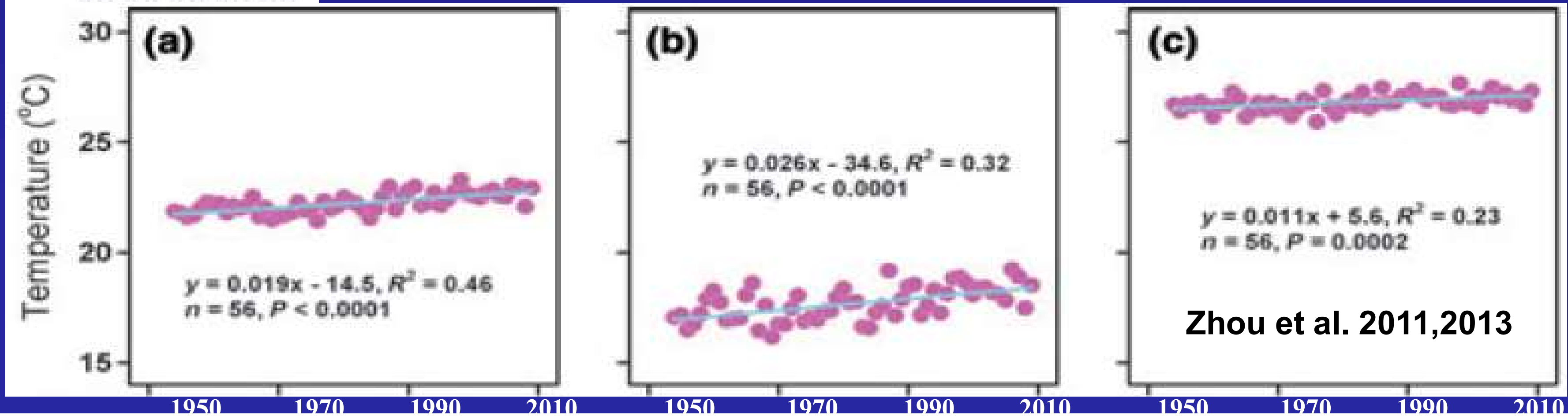
Dinghushan:

Precipitation no change, but no-rain days increased, small rain days decreased.



Whole year annual T increment 0.019 ℃
Dry season annual T increment 0.026 ℃
Wet season annual T increment 0.011 ℃





Zhou et al. 2011,2013

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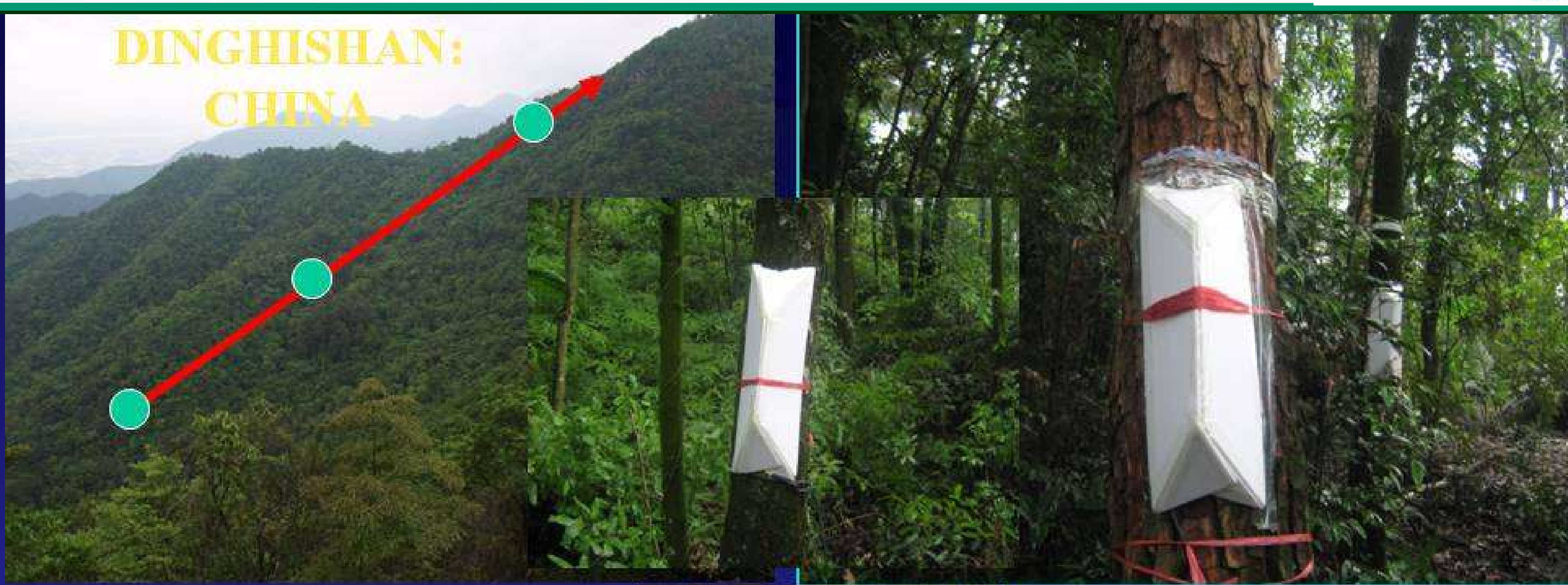
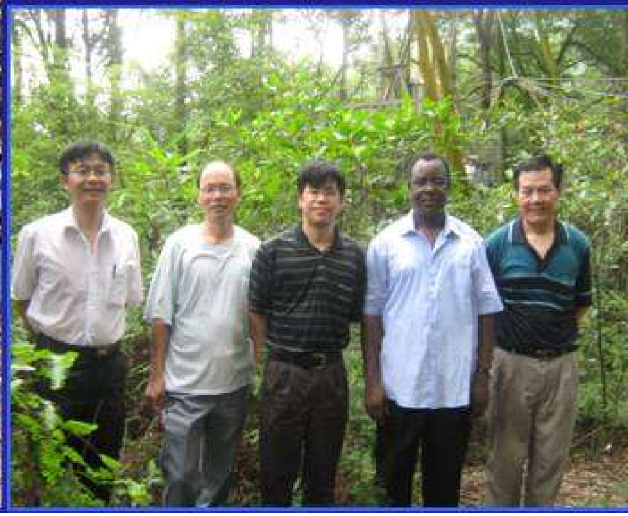
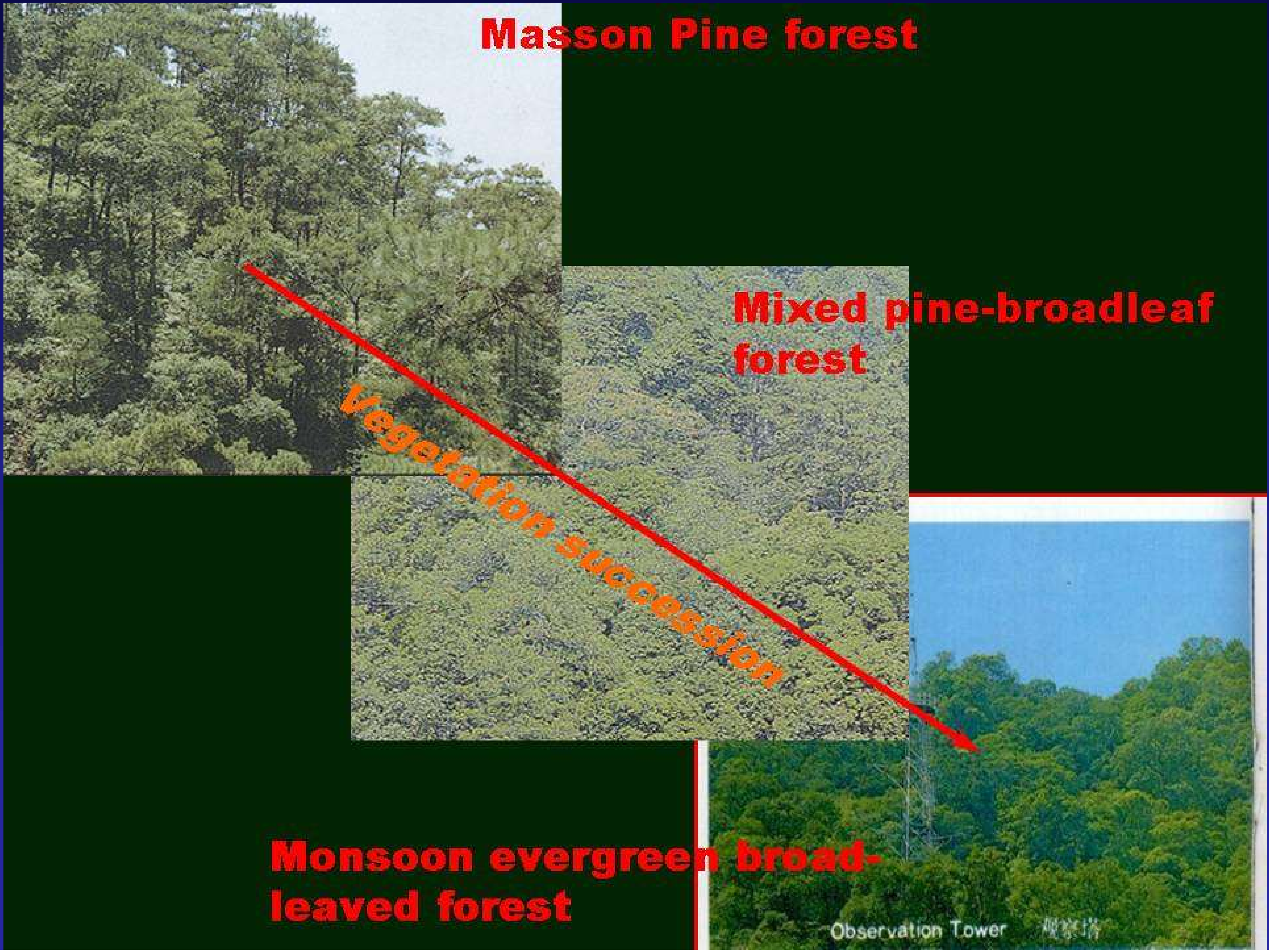
Dinghushan Forest Ecosystem Research Station






Masson Pine forest
Mixed pine-broadleaf forest
Vegetation succession
Monsoon evergreen broad-leaved forest
Observation Tower


气象观测场全景


27 11:35AM


森林小气候梯度观


27 3:00PM

1.3 Methods

a) Water flux measurements via the eddy covariance methodology

$$\lambda E = \lambda \rho (\overline{w'q'})$$

b) Semi-empirical ET model

$$E = E_0 \left\{ 1 + \frac{s}{E_0} - \left[1 + \left(\frac{s}{E_0} \right)^{\frac{Nh}{h^2-h-1}+N+1} \right]^{\frac{1}{\frac{Nh}{h^2-h-1}+N+1}} \right\}$$

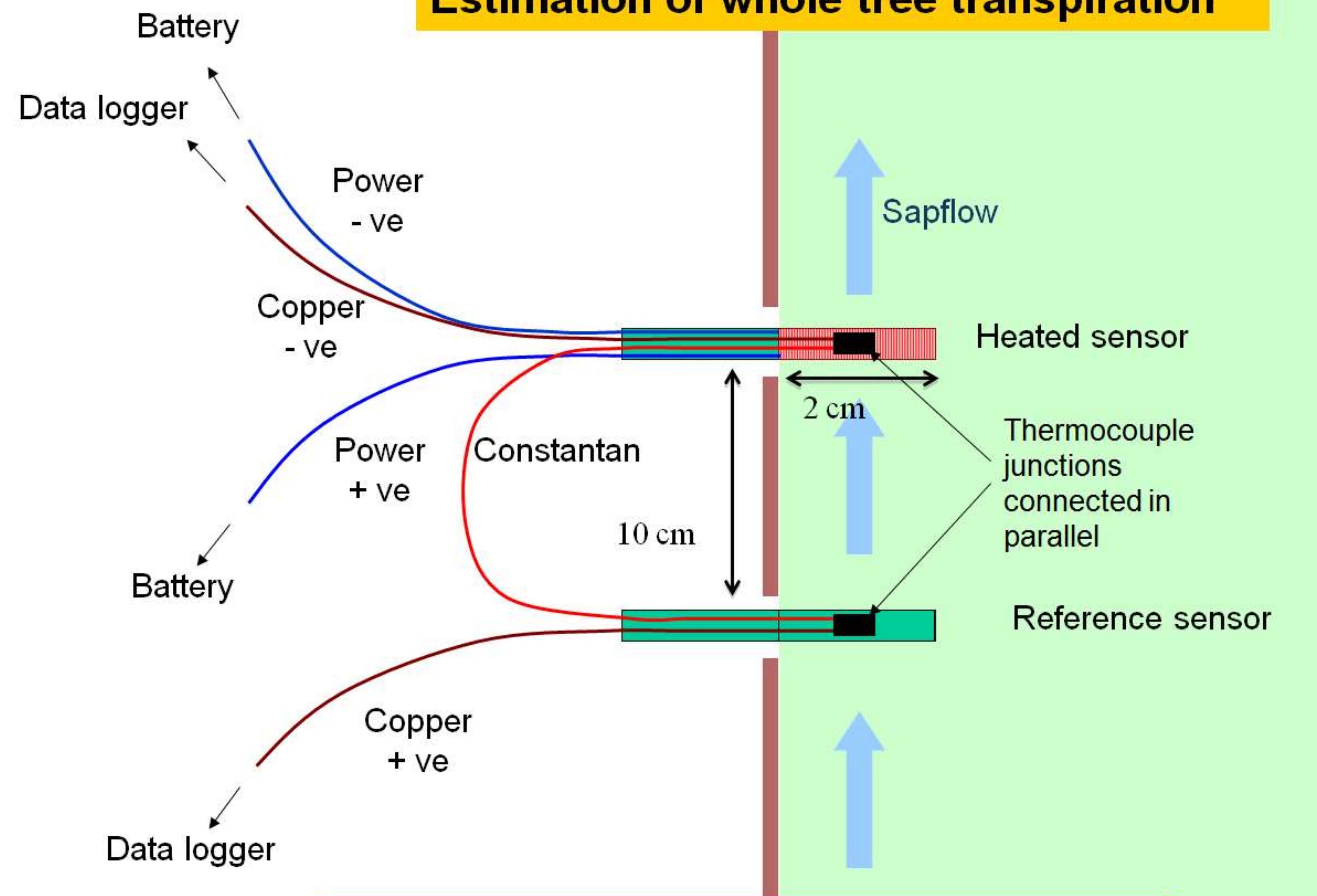
where E is the actual ET (mm), E_0 is the rate of ET under unlimited soil water conditions (i.e., the PET rate in mm), s is rainfall (mm), h is atmospheric relative humidity and N is a model parameter varying from zero to infinity. Here, we estimate the key empirical parameter $N = 0.85$

a) Catchment water balance measurements

b) Sap flow measurements

$$E = P - R \pm \Delta W$$

Estimation of whole tree transpiration



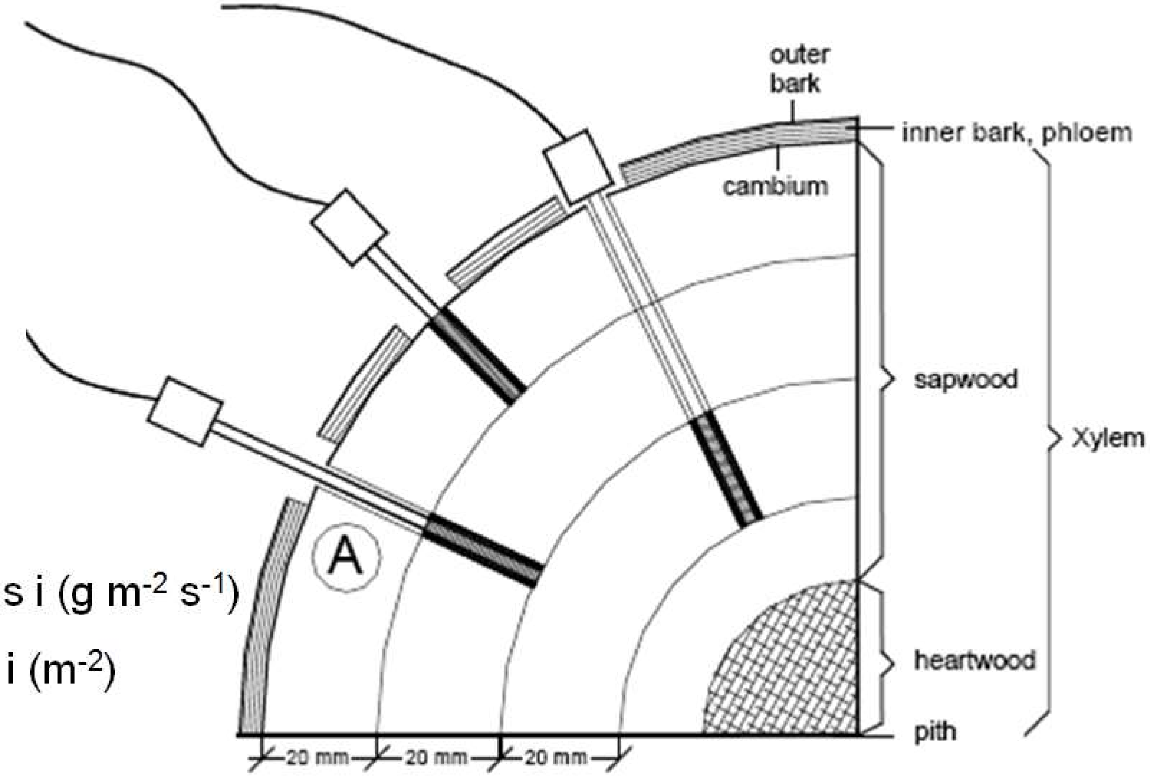
Heat dissipation techniques Granier 1985, 1987

Estimation of whole-tree sap flow

- Total sap flow of the tree (Q_t)

= Sap flux density (J_{si}) x Cross-section area of sap wood (A_{Si})

$$Q_t = \sum_{i=1}^{i=n} \left(J_{s\,i} \cdot A_{s\,i} \right)$$



J_{si}: sap flow density of annulus i (g m^{-2} s^{-1})

A_{si}: sapwood area of annulus i (m^{-2})

2. Research Goals

1) Examine the consistency and feasibility of estimates between the eddy covariance and sap flow methods in providing estimates of ET and transpiration component on temporal scales
2) Investigate the different responses of transpiration and evaporation to environmental factors
3) How the Complexity in landscape structure leads to variable water use patterns on mountains as a result of coordination between localized stand characteristics and canopy processes

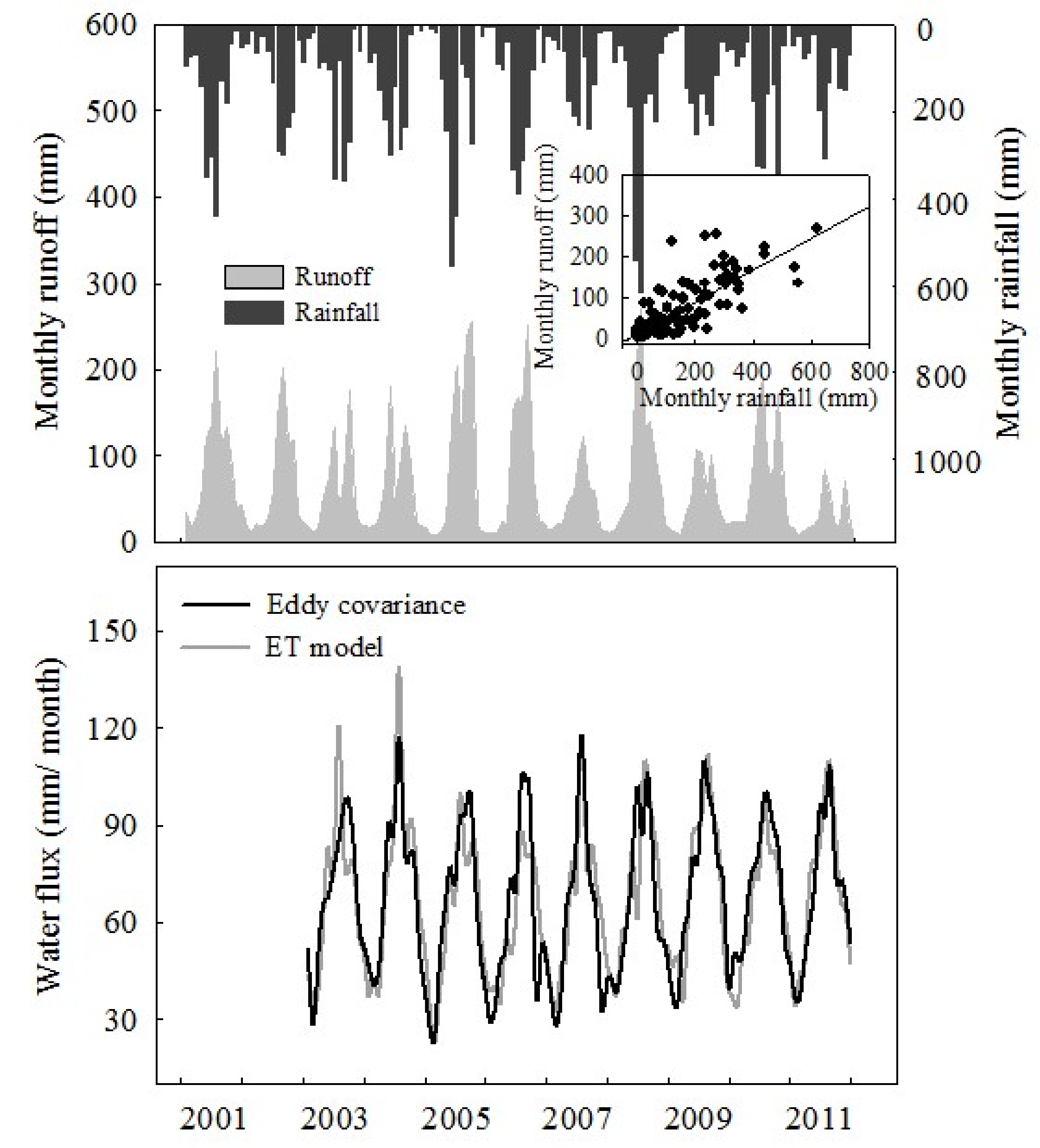
3. Data Analysis & Results

3.1 Evapotranspiration(ET) partitioning

Total ET in Dinghushan forested watershed

Year	Precipitation (mm)			ET (mm) Catchment water balance			ET (mm) Semi-empirical ET model			ET (mm) Eddy covariance method		
	Wet season	Dry season	Annual	Wet season	Dry season	Annual	Wet season	Dry season	Annual	Wet season	Dry season	Annual
2001	1545.3	343.9	1889.2	783.7	100.8	884.5						
2002	1041.7	439.2	1480.9	486.3	217.9	704.2						
2003	1247.1	185.8	1432.9	706.7	58.3	765.0	499.2	303.8	803.0	487.8	326.9	814.7
2004	1205.8	230.6	1436.4	607.5	106.4	713.9	548.6	320.0	868.6	531.2	304.6	835.7
2005	1721.6	183.6	1905.2	744.9	114.1	859.0	455.6	285.8	741.5	499.4	265.8	765.3
2006	1410.3	316.7	1727.0	586.9	209.3	796.2	417.5	296.2	713.7	497.3	250.7	754.5
2007	1058.6	193.8	1252.4	613.0	96.6	709.6	442.1	336.6	778.7	498.4	240.4	738.9
2008	1900.6	320.4	2221.0	689.6	149.6	839.2	504.5	326.1	830.5	516.2	289.3	805.5
2009	1132.7	307.7	1440.4	675.9	185.9	861.8	540.7	309.9	850.5	526.9	317.9	844.8
2010	1471.7	300.7	1772.3	727.4	131.4	858.8	468.7	313.0	781.7	514.3	333.3	847.6
2011	858.8	386.8	1245.6	634.4	251.0	885.3	540.8	305.8	846.5	508.5	318.6	827.1
Ave.	1326.7	291.7	1618.5	659.7	147.4	807.1	490.8	310.8	801.6	508.9	294.2	803.8
CV (%)	22.6	27.6	17.3	11.7	37.5	8.2	8.7	4.4	5.9	2.5	10.5	4.6

Amount of precipitation (mm) and ET (mm) estimated by the catchment water balance, semi-empirical ET model and the eddy covariance methods in the dry season (October-March), wet season (April-September) and whole year.



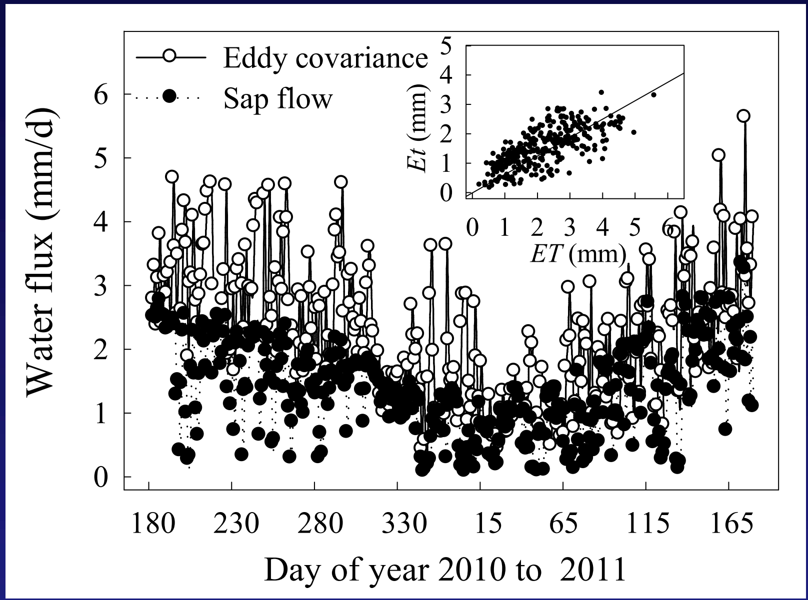
2003-2011, Mean annual Precipitation 1605.2 mm (1245.6~2221.0mm).

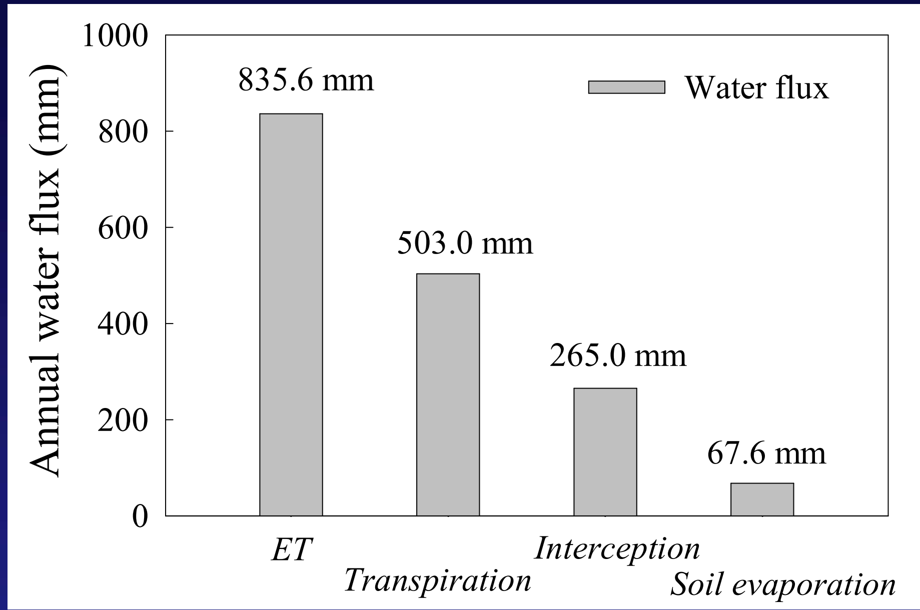
2003-2011, Mean annual ET ： 809.9±62.8 mm (water balance)、803.8±38.6 mm (Semi-empirical model)、801.6±49.5 mm (eddy covariance).

ET accounted for 50.2% precipitation。

Comparisons of the monthly water flux estimated by catchment water balance, ET model and eddy covariance

Partition of total ET



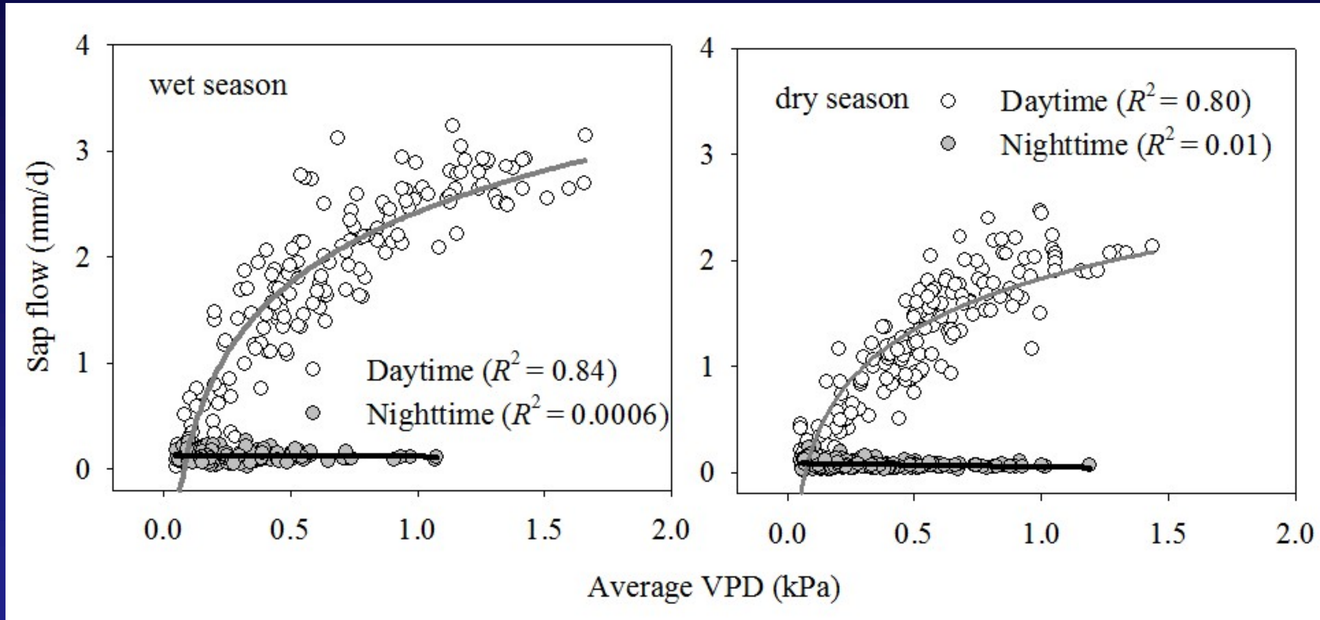


Daily estimates of ET from eddy covariance and transpiration (*Et*) from sap flow during 2010-2011.

Annual water flux, including ET and its components, during 2010-2011. ET and transpiration were measured with the eddy covariance and sap flow methods, and the interception evaporation was calculated by the average rainfall interception rates of the watershed forests

Daily scale Et vs. ET Significantly, P < 0.01) 。2010-2011, annual ET 503.0 mm, accounted for ET(835.6 mm)60.2%。Soil evaporation accounted for ET 8.1%。

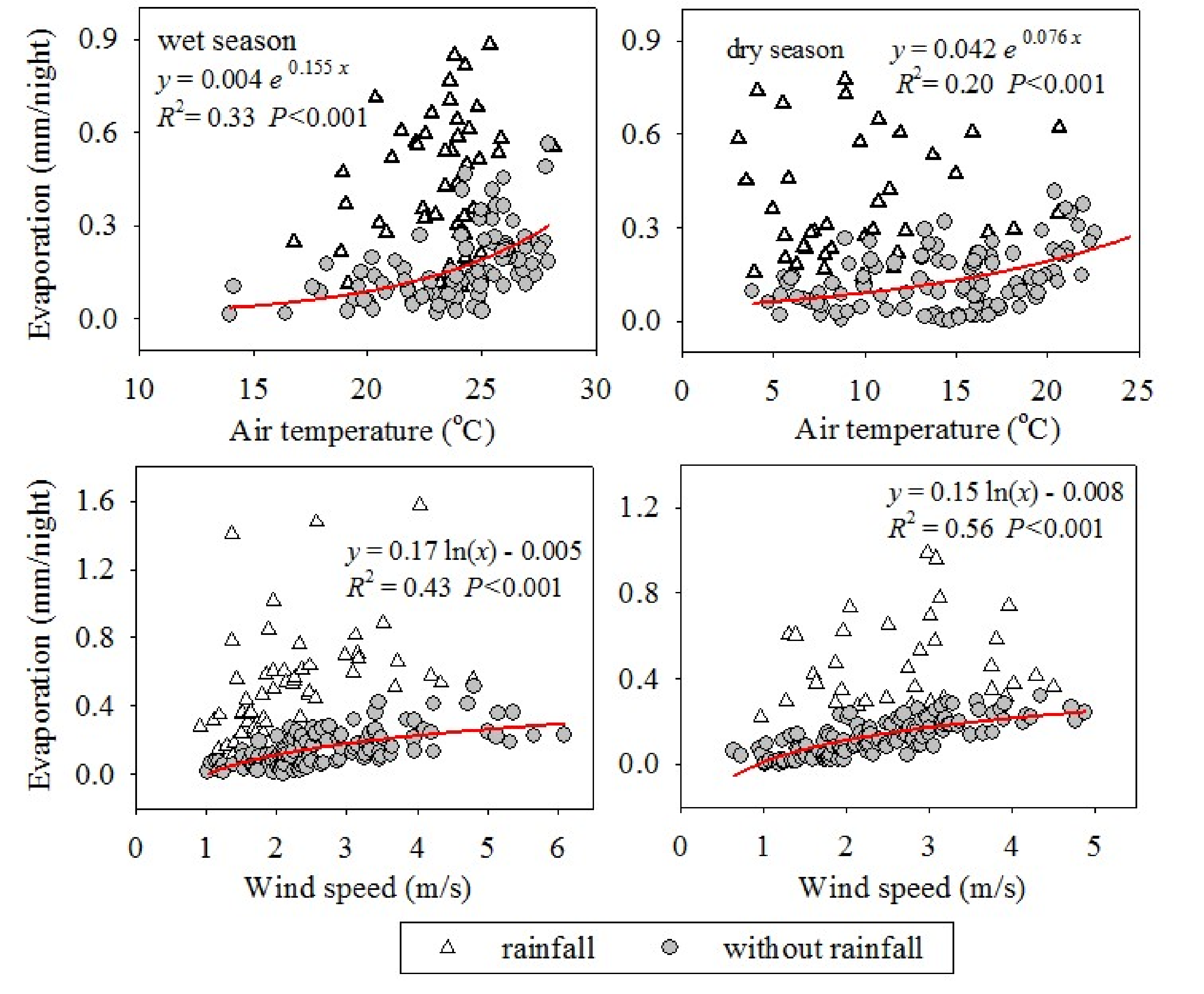
Transpiration (Et) and environmental factors



Sensitivity of sap flow to vapor pressure deficit (VPD) for different seasons as measured by the thermal dissipation probe method. Sensitivity at night (○) and during the day (●) are shown

Daytime，Et dominated by VPD significantly。Nighttime, sap flow was very weak. Daytime transpiration exhibited a logarithmic increase with increases in the vapor pressure deficit (VPD) on daily scale in both the wet and dry seasons, and tended to level off when the VPD was > 1 kPa due to the stomatal regulation of transpiration

Soil evaporation

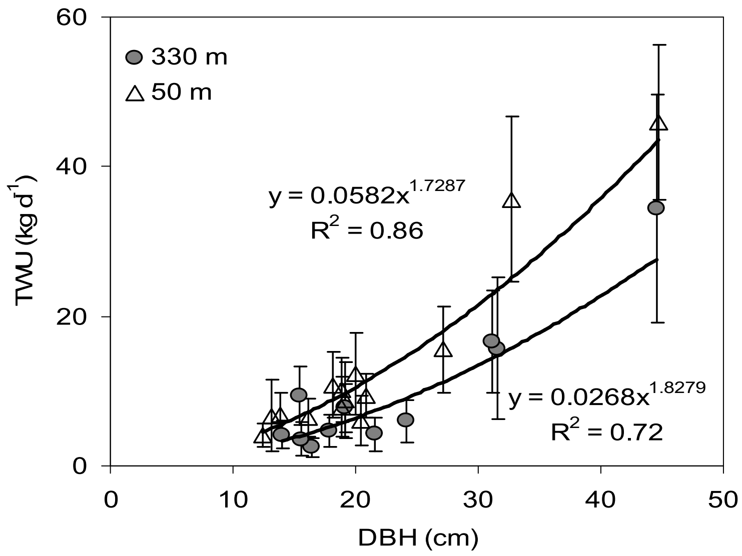


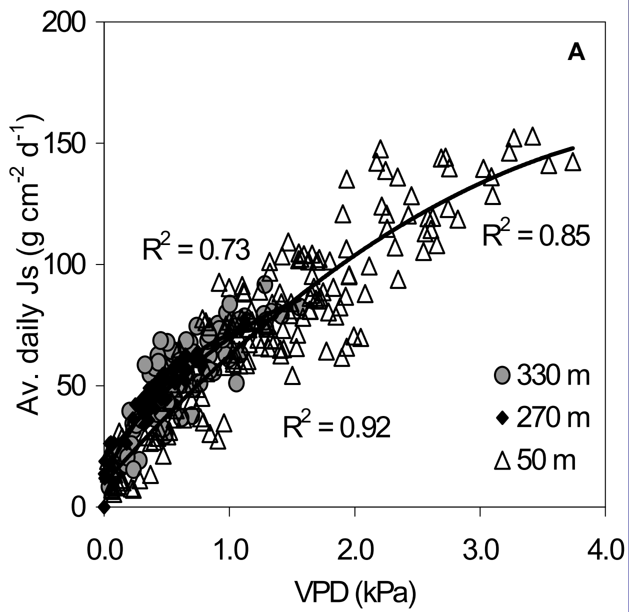
Soil evaporation dominated by T and wind speed

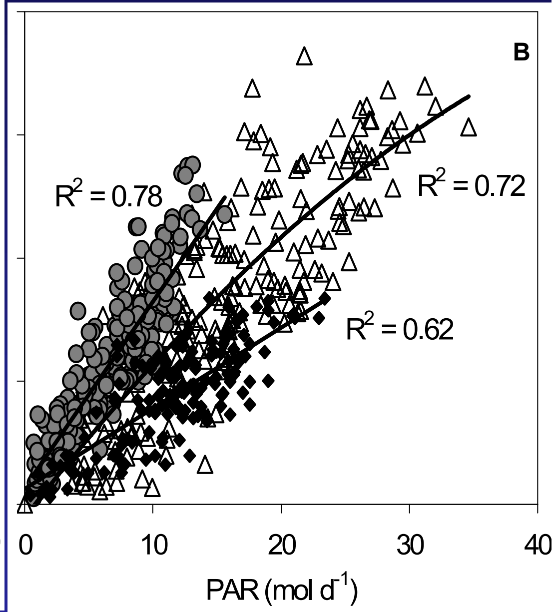
Evaporation (nighttime water flux from eddy covariance) in relation to air temperature and wind speed during the wet and dry seasons

3.2 water use patterns

Influence of tree size on tree water use

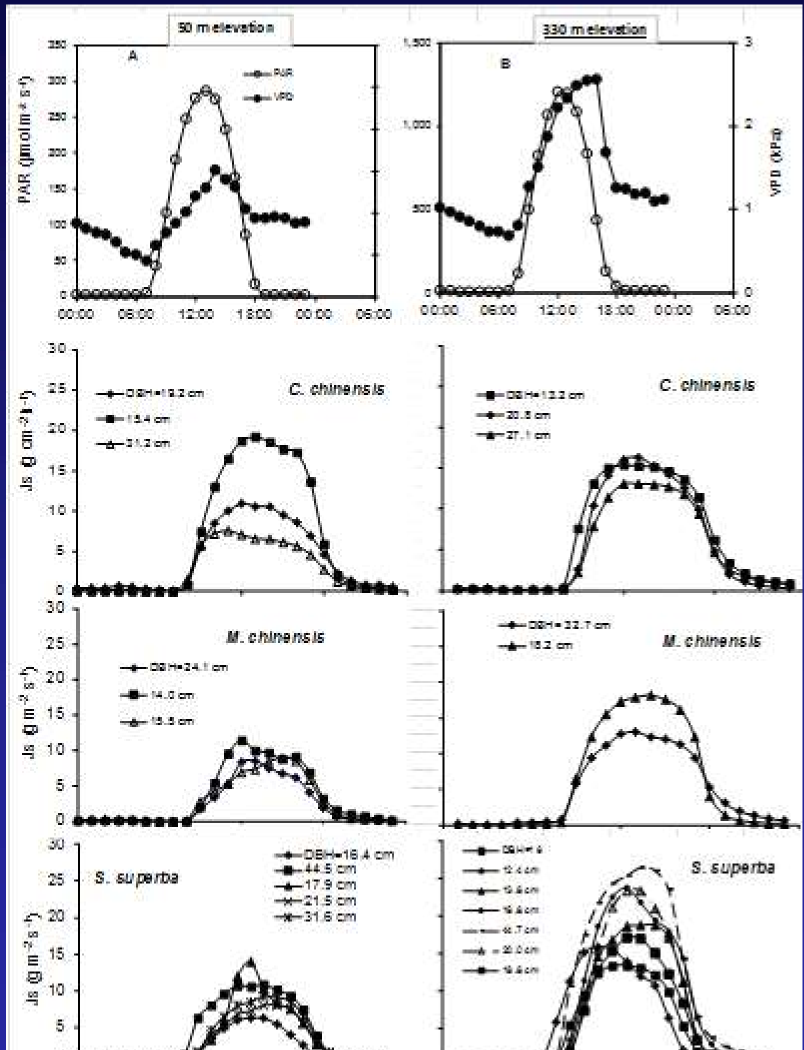


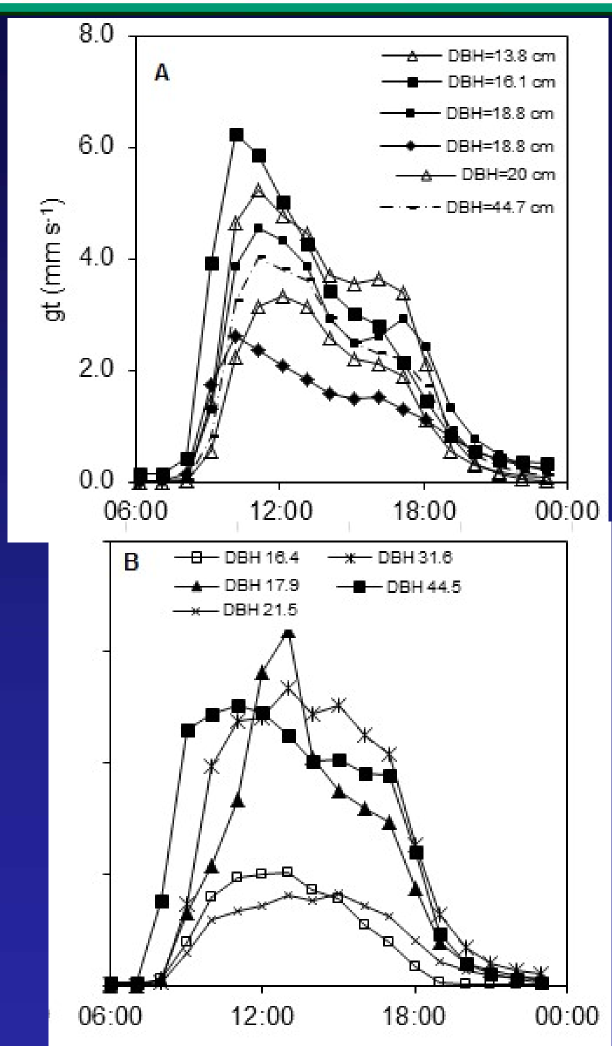




Tree sapwood area was correlated with DBH irrespective of species and location. Trees converge in their water use irrespective of species

Otieno & Li, 2015
Li et al., 2017





Daily patterns of the total canopy conductance (gt) of trees of S. superba in the (A) 50 m and (B) 330 m forest stands.

Diurnal patterns of sap flux density (Js) within the outer 20 mm sapwood on a typical sunny day for all the measured trees. The figures are grouped according to tree species.

4. Summary

1. The estimates of annual ET using the eddy covariance, semi-empirical ET model and catchment water balance techniques were in close agreement, averaging 801.6 ± 49.5 mm, 803.8 ± 38.6 mm and 810.0 ± 62.8 mm per year, respectively, amounting to an average of approximately 50.2% of the mean annual rainfall.
2. Qualitative similarities in seasonal and diurnal variation were observed between the sap flow and eddy covariance estimates of water flux.
3. Sap flow estimates of transpiration were approximately 61.0% of the annual ET estimated with the eddy covariance technique.

4. Summary

4. Soil evaporation was an important contributor (8.2%) to the total annual water flux. soil evaporation is primarily a climate-driven process, with air temperature and wind speed as the predominant driving forces.

5. Tree sapwood area (SA) was correlated with the diameter at breast height (DBH) irrespective of species and location within the forest catchment.

6. Differences between the stands were significant. Within a stand, TWU was correlated with DBH irrespective of species.

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