International Symposium on Southeast Asian Tropical Rain Forest Research related with Climate Change and Biodiversity

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A common character of forest evapotranspiration in response to climate change

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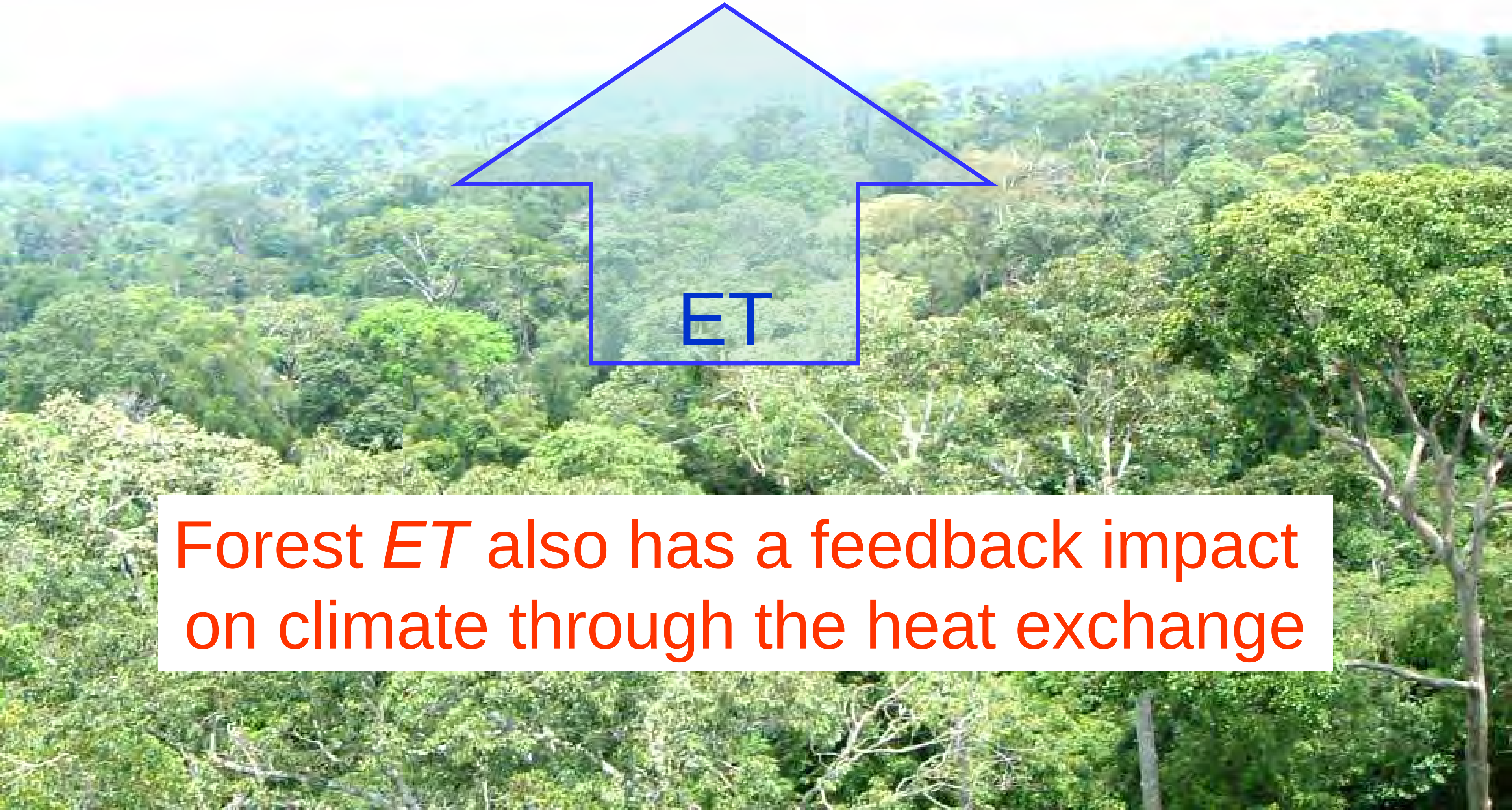
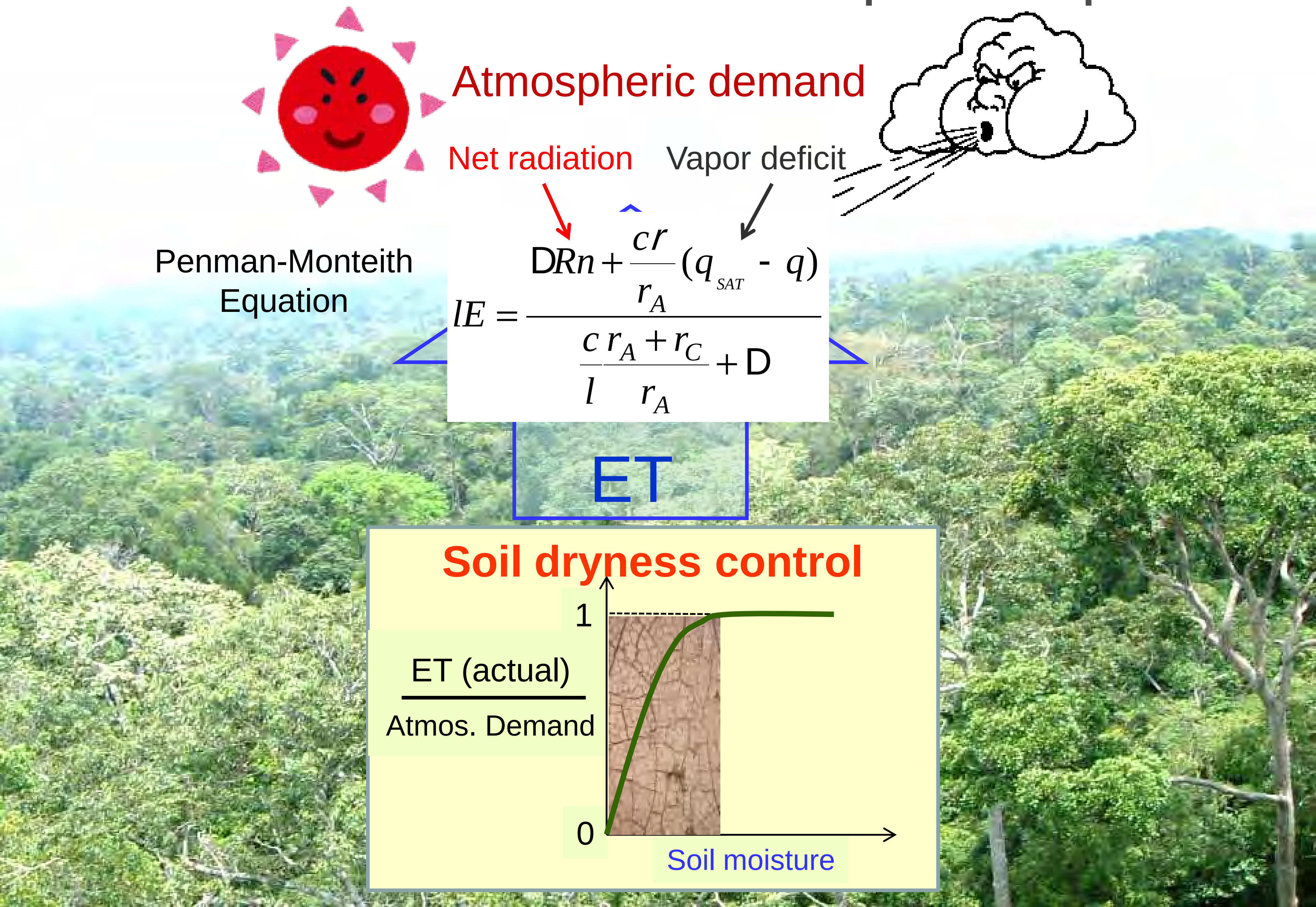
INTRODUCRTION *E*vapo*T*ranspiration

ET is controlled by
the atmospheric demand
but also by soil dryness



Forest *ET* also has a feedback impact
on climate through the heat exchange

INTRODUCRTION Evapotranspiration



$$lE = \frac{D Rn + \frac{c r}{r_A}(q_{SAT} - q)}{\frac{c}{l}\frac{r_A + r_C}{r_A} + D}$$

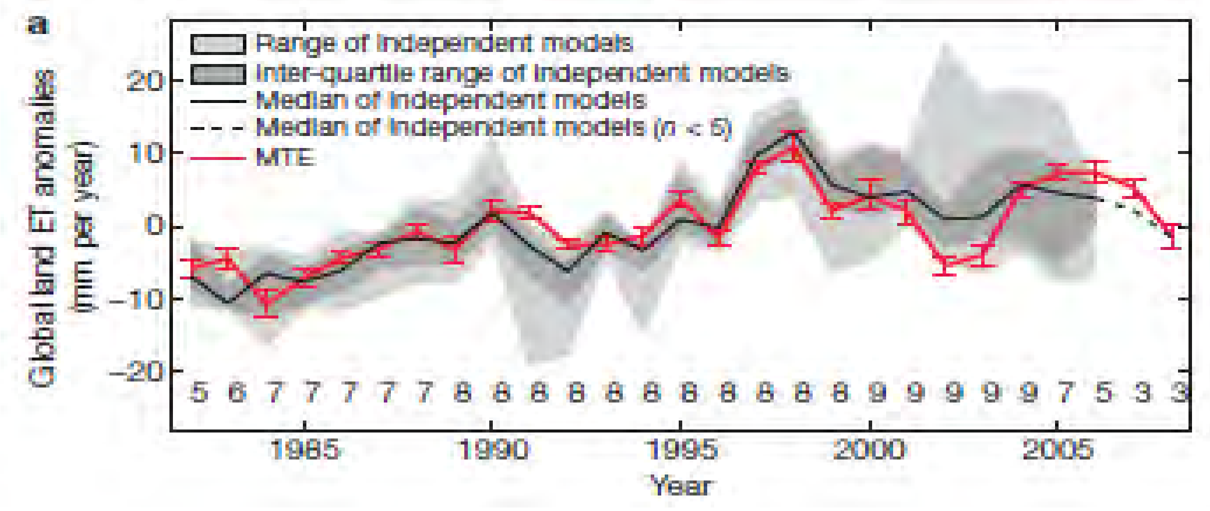
INTRODUCRTION Main Question

Forest uses much water as ET.

Will climate warming accelerate it?

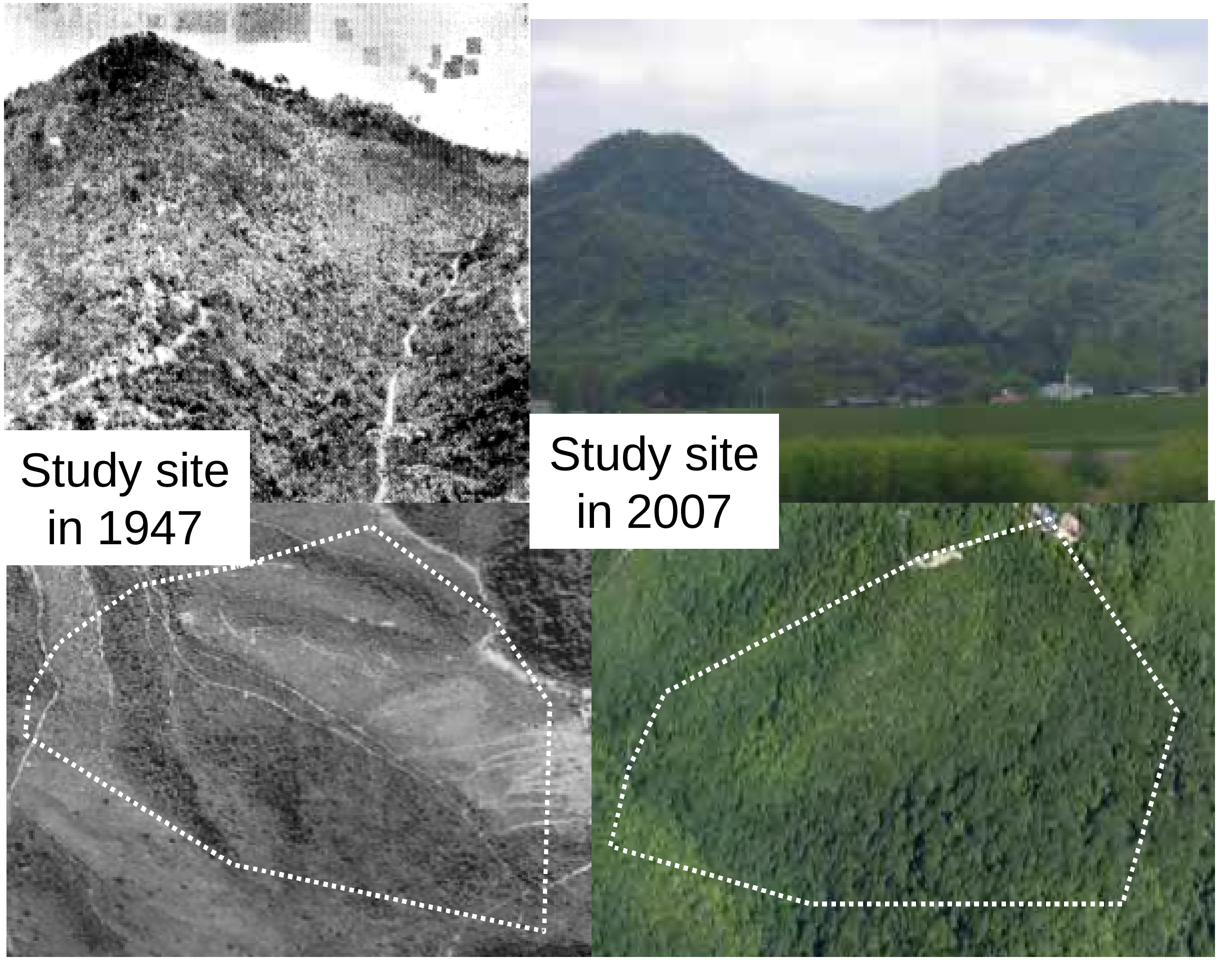
A report suggests its decrease due to soil water control

(Jung et al.: Nature, 1910)



The purpose is to detect the nature and trend of forest ET from a Long-Term catchment study

METHODS



The purpose is to detect the nature and trend of forest ET from a Long-Term catchment study

METHODS

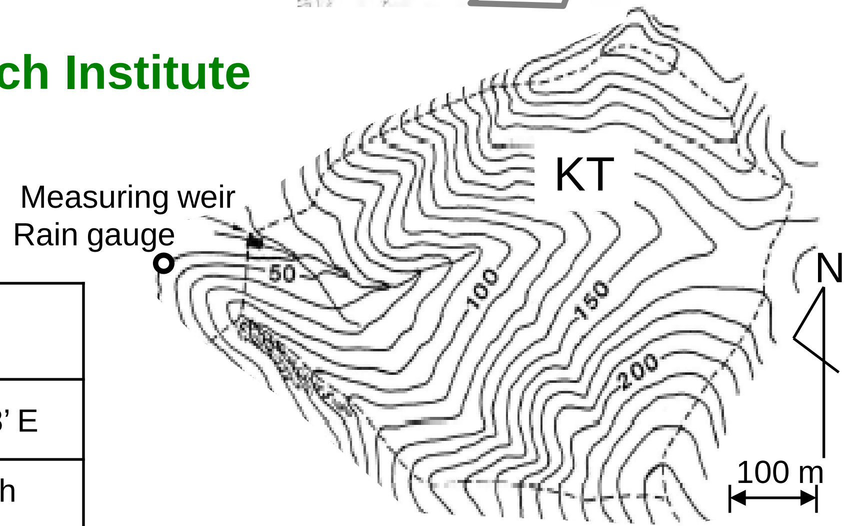
Site

Tatsunokuchi-yama Experimental Forest

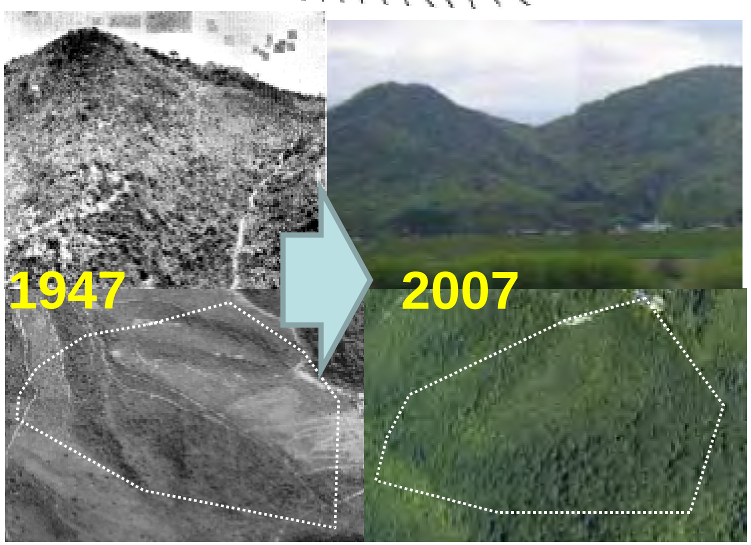
conducted by

Forestry and Forest Products Research Institute

Since 1937



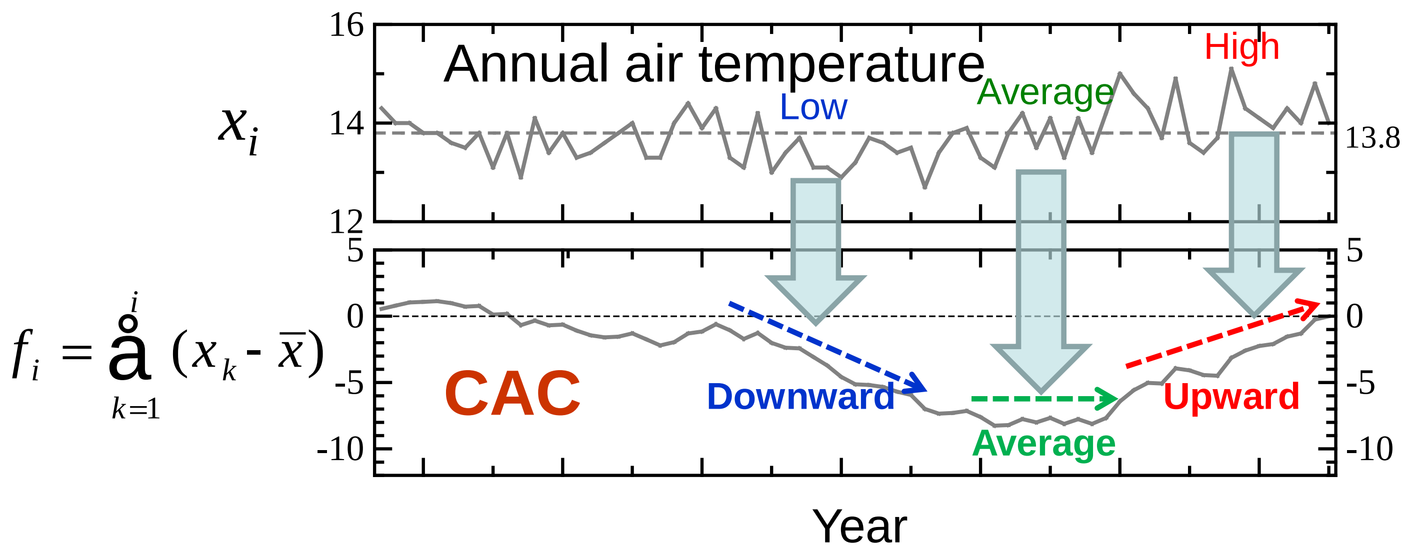
Profile of KT catchments	
Location	Near Okayama 34 ° 42’ N, 133 ° 58’ E
Geology	Permian accretionary complex with quartz porphyry (the north portion)
Precipitation	**1220 mm** (annual amount, 1937-2005)
Air temperature	**13.8 ˚C** (annual av. 1937-2005)
Soil	Clay loam
Catchment area	17.27ha
Slope	28.4 °
Slope length	123m
Vegetation changes	
1937	Natural **pine** forest
1944-47	Pine **death** clearcut
1948-around 1957	**Cutover**
Around 1958 -	Growth of **deciduous** forest



Cumulative **A**nomalies **C**urve (Lozowski, 1989; Ding, 2007) AC

$$f_i = \sum_{k=1}^{i} (x_k - \bar{x})$$

was used to detect a trend of the long-term hydrometeorological records



Cumulative anomalies curve

The trend can be examined by CAC

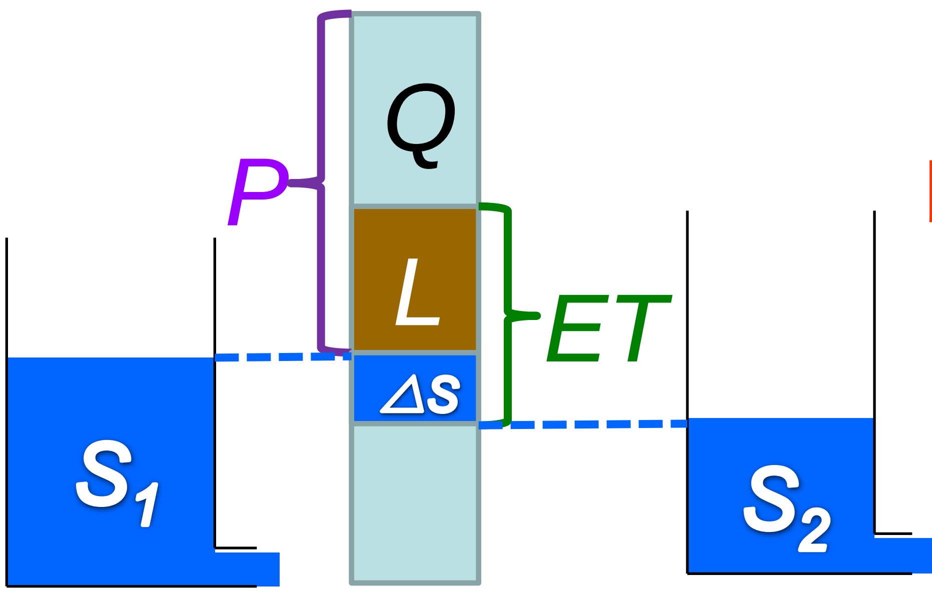
METHODS

Storage effect on ET

*L*oss from water balance as Rainfall (*P*) –Runoff (*Q*) is lower than *E*vapo*T*ranspiration by storage decrease

$$S_2 - S_1 = \Delta S = P - Q - ET = L - ET$$

$$ET = L - \Delta S$$



ET is larger than *L*=*P*-*Q* because $\Delta S = S_2 - S_1$

METHODS Storage effect on *ET*

*L*oss from water balance as Rainfall (*P*) –Runoff (*Q*) is lower than *E*vapo*T*ranspiration by storage decrease

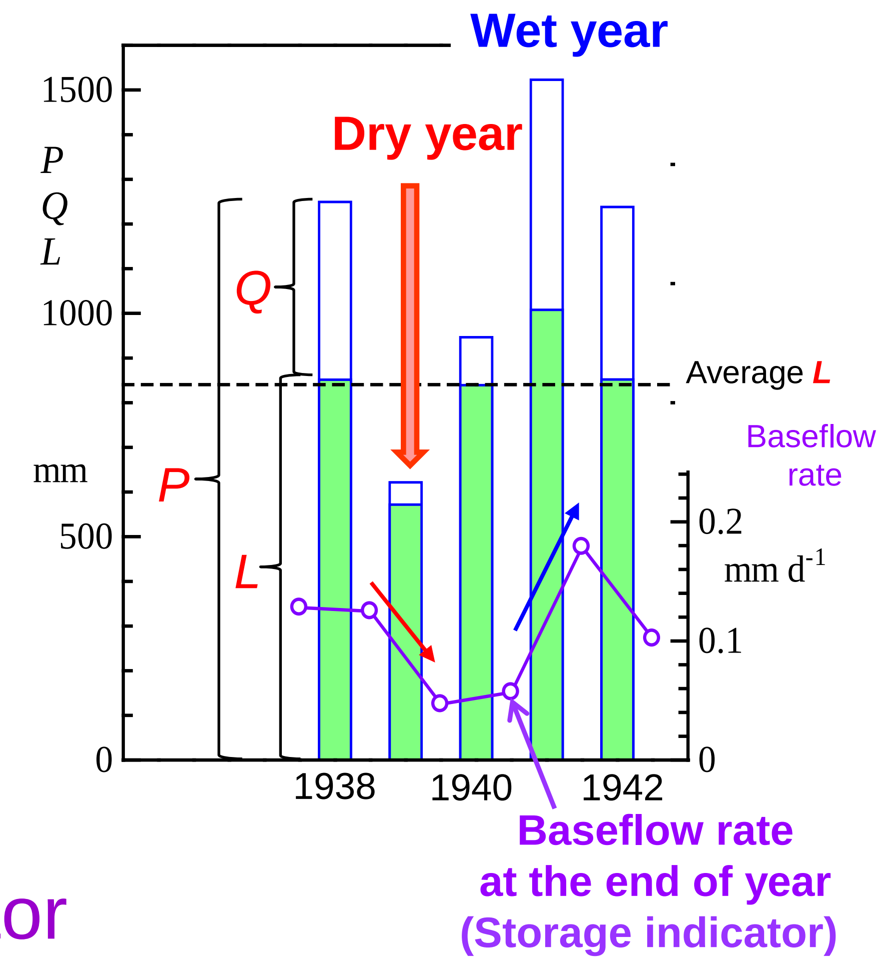
L in a dry year looks very small compared to that in a usual year,

but the baseflow rate at the end of year decreases than that of the previous year.

suggesting an underestimation of ET in this dry year.

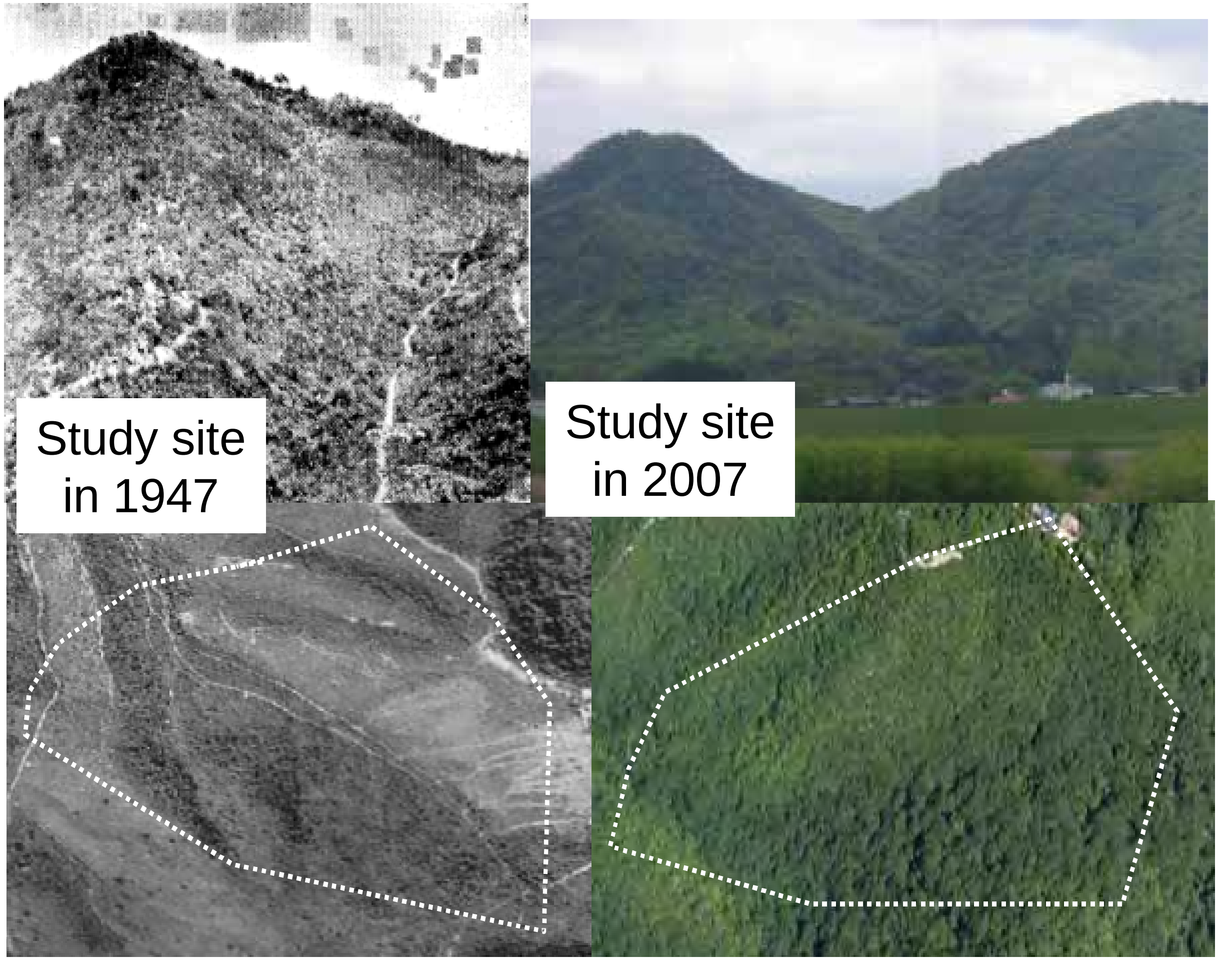
ET in each year involves a storage change effect

Baseflow rate as its indicator



Annual water balance

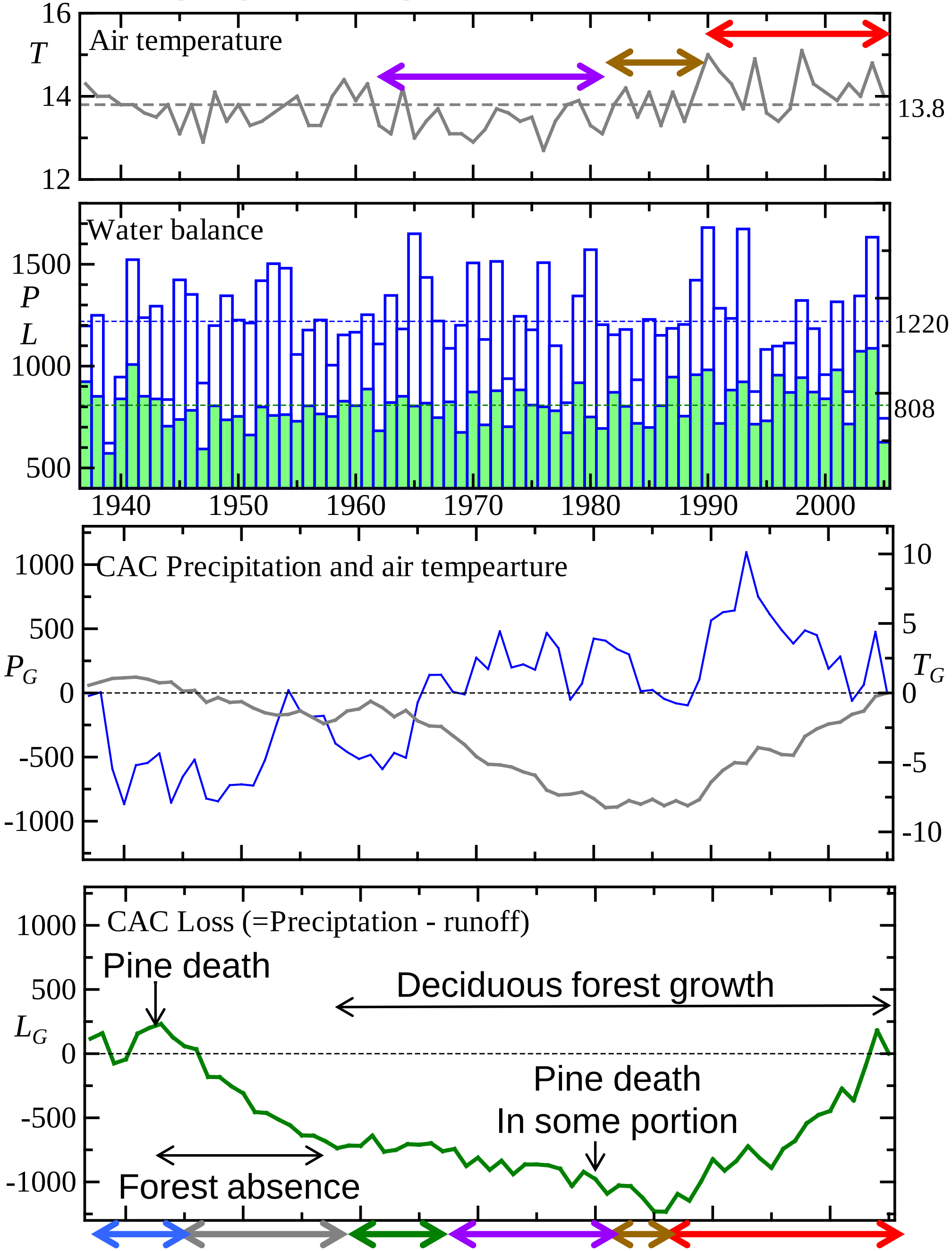
RESULTS



The purpose is to detect the nature and trend of forest ET from a Long-Term catchment study

RESULTS

Long-term trend



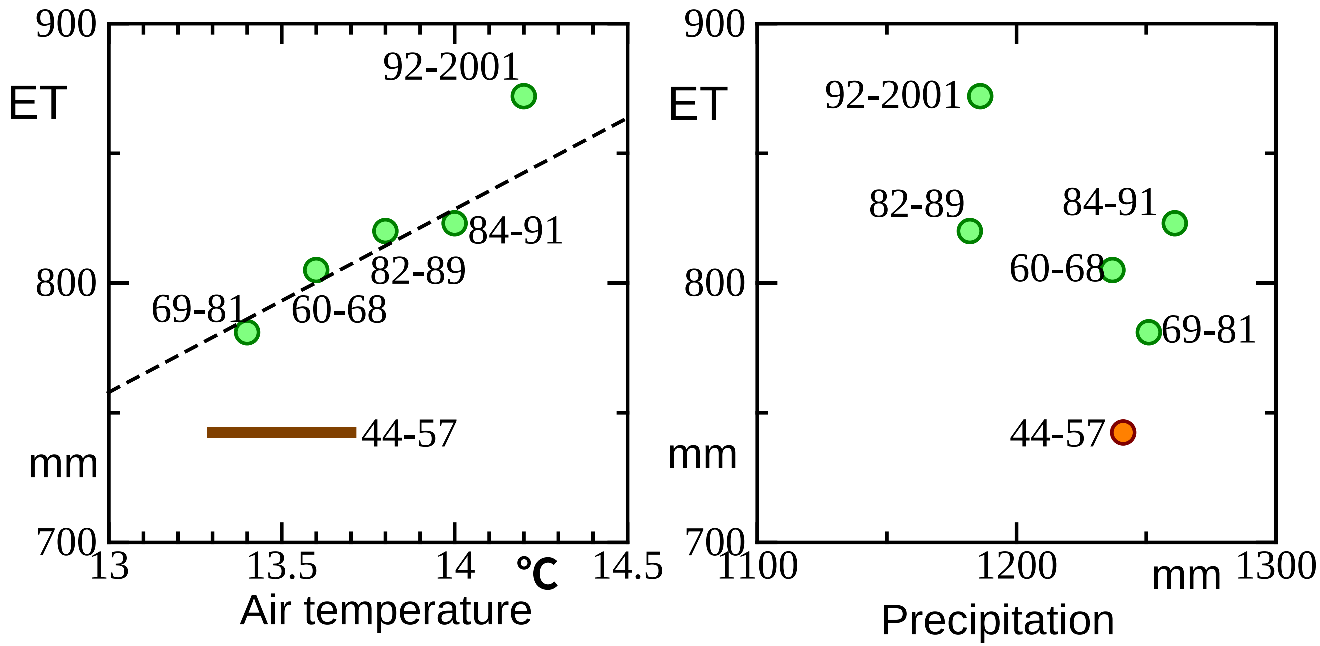
Air temperature
- low in 1960s and 70s,
- average in 1980s
- high after 1990

Loss is flat compared to Precipitation

Loss
- average before pine death in 1943
- low for the forest absence 44-58
- average around 1960
- slightly low during 1960s and 70s
- low after pine death in 1980
- high after 1987

RESULTS Effect of climate

Mean ET was calculated in each period with the negligible storage effect



ET became larger with temperature increase and precipitation decrease

The dependency of ET on temperature was clearer

ET was enormously large in 1992-2001

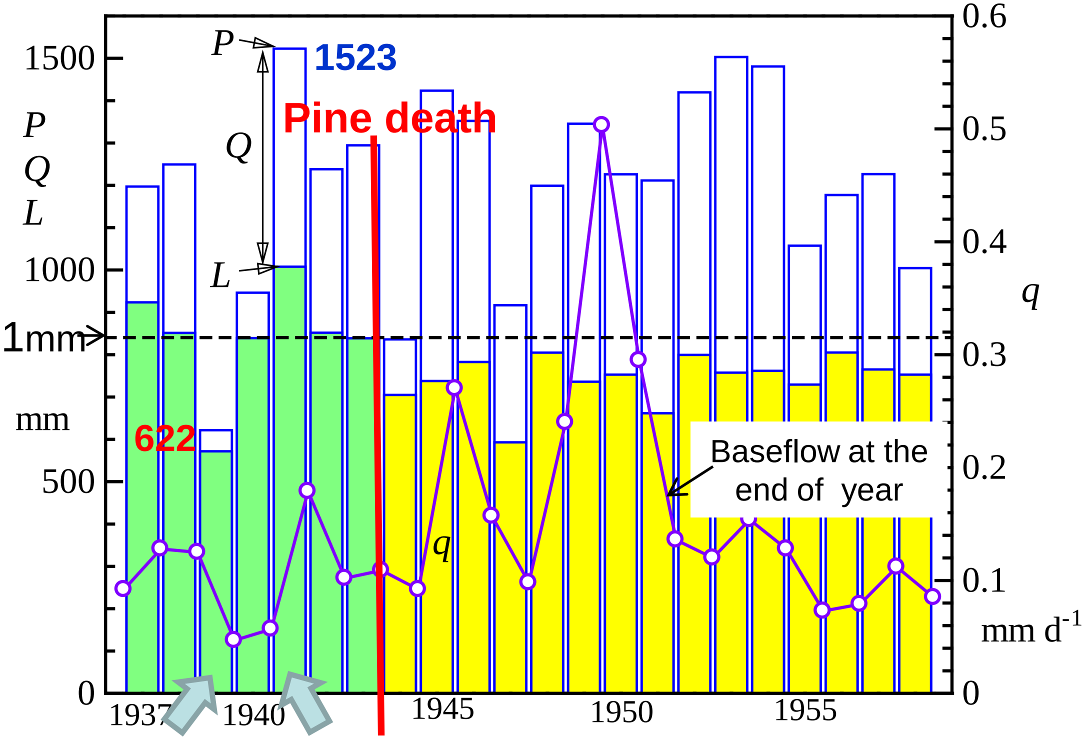
ET is low during the forest absence in 1944-57 regardless of the climate condition

RESULTS ET in each year

The ET amount and the effect of storage were compared before and after the pine death in 1943

ET was smaller after pine death

Mean loss before 1943



ET was underestimated in a dry year (1939)

P=622 mm, L= 572 mm

and overestimated in a wet year (1941)

P=1523 mm, L= 1008 mm

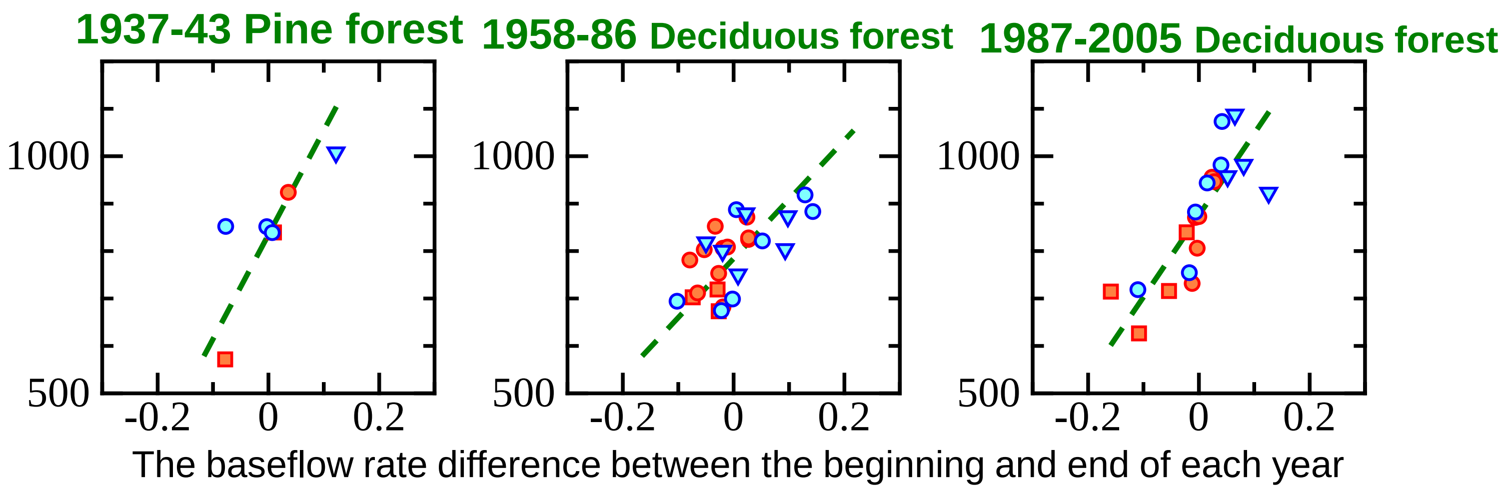
Decrease of baseflow in a dry year

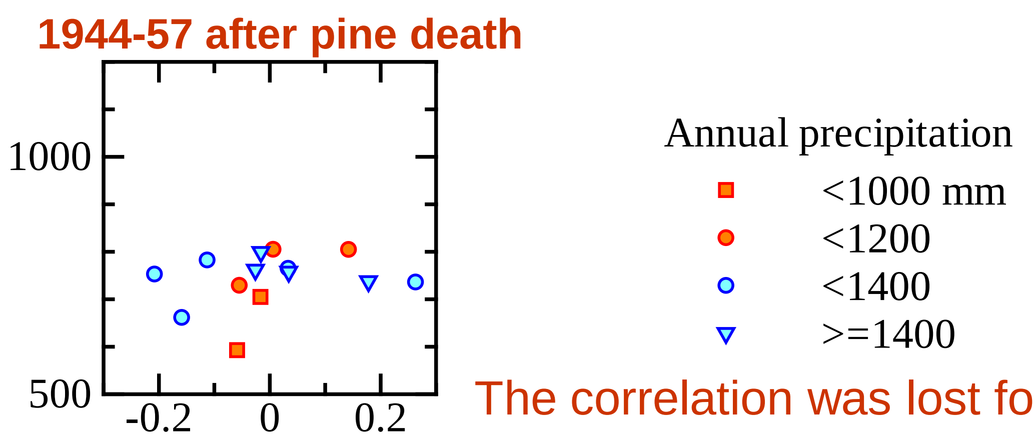
Increase of baseflow in a wet year

This storage effect was only for forest but lost after the pine death

RESULTS Forest ET against dryness

Correlation of the annual loss to the baseflow increase / decrease in each year suggests a sustainability of ET by consuming water storage





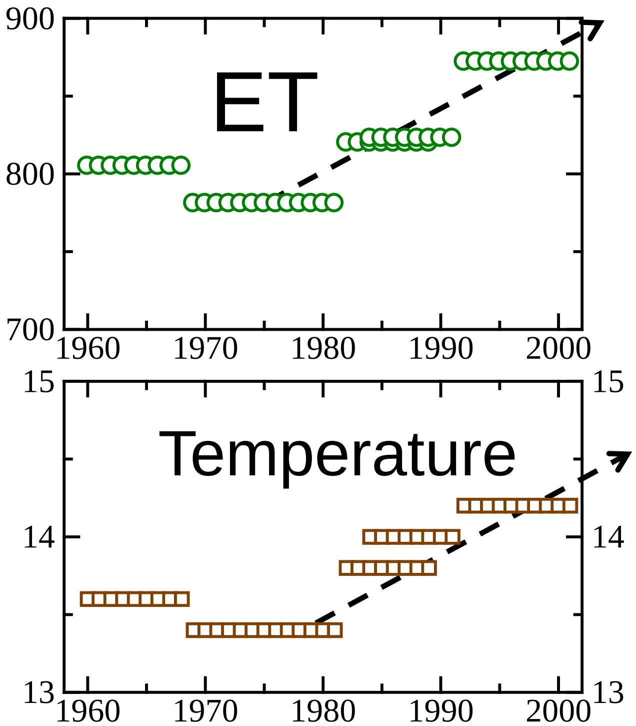
The correlation was lost for the forest absence

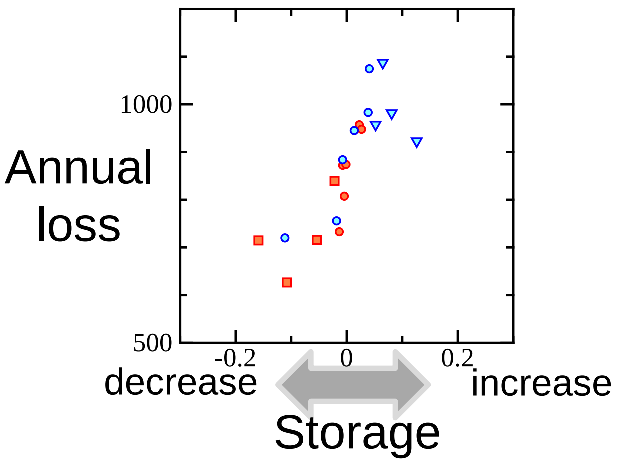
Only forest ET is persistent using soil water in a dry year

DISCUSSION

DISCUSSION *ET* follows demand

Our analysis on catchment water balance in KT demonstrates forest ET continuously responded to the atmospheric demand (temperature)

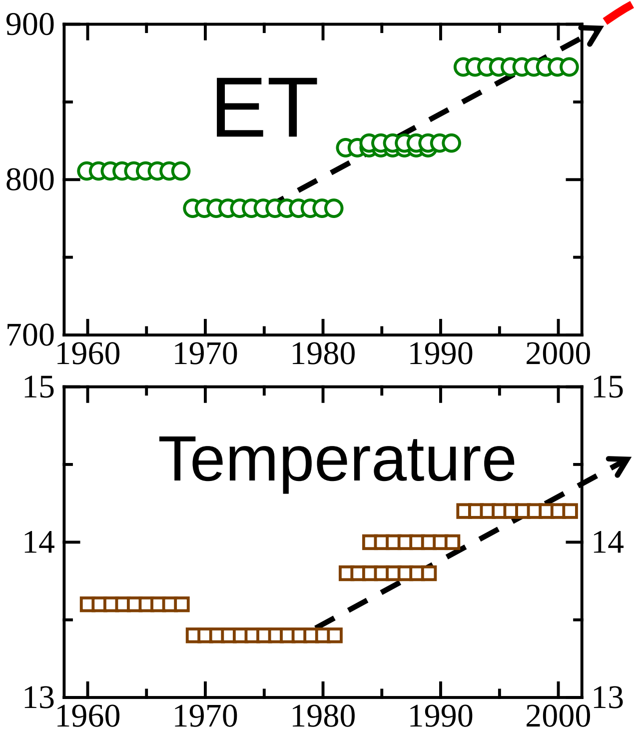




Forest ET was not controlled by the soil dryness

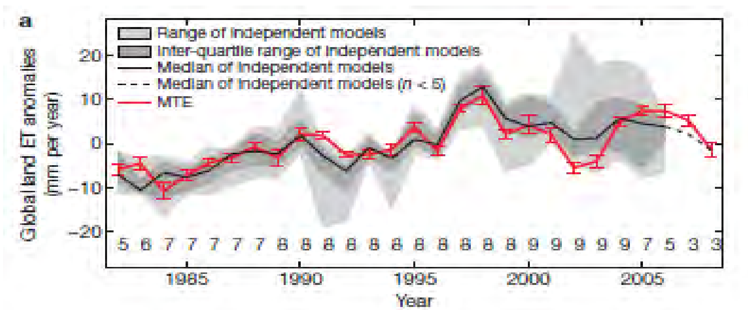
Forest follows the atmospheric demand regardless of dryness

DISCUSSION *ET* follows demand



Further warming may
reduce forest *ET*
by soil dryness

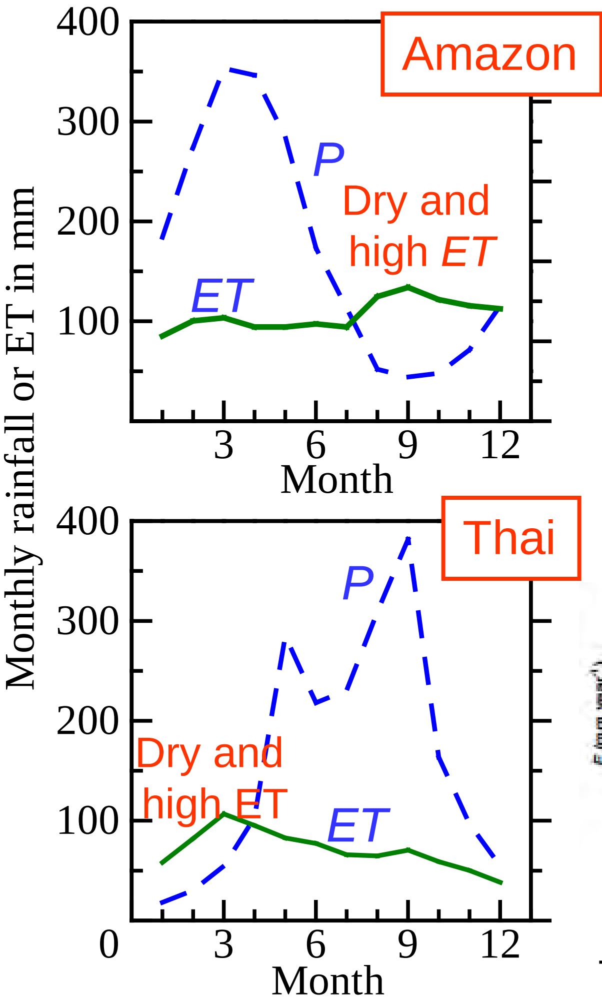
A report suggests its decrease due to soil water control
(Jung et al.: Nature, 1910)



Ecosystem resilience is at a crisis point
by the present quick climate change

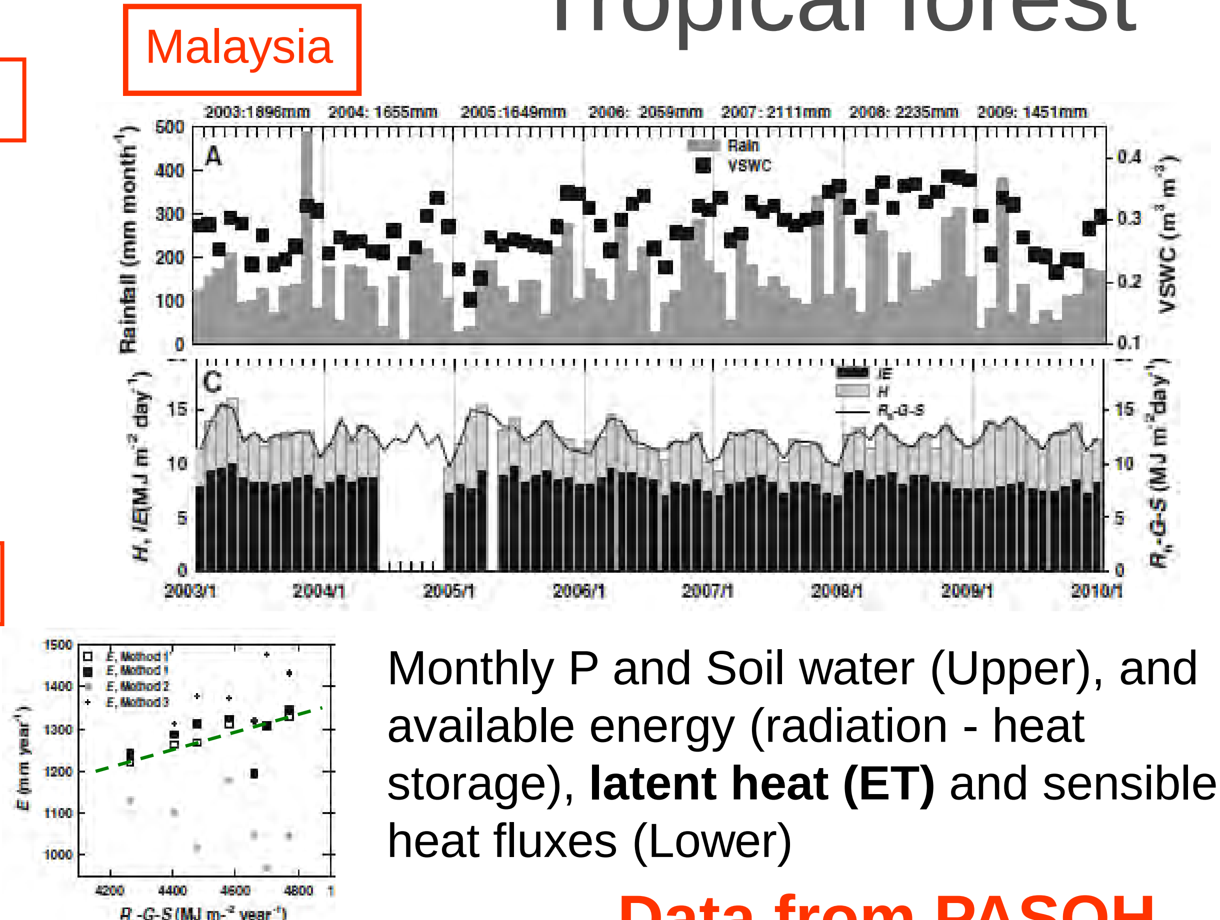
DISCUSSION

DISCUSSION Tropical forest



Monthly *ET* with *P* amounts in Amazonian rainforest (Ducke) and Thai hill- evergreen forest (Kog-Ma)

Shuttleworth: Proc. R. Soc. Lond., B233,1988
Tanaka et al.: J. Geophysic.Res. 108, 2003



Monthly P and Soil water (Upper), and available energy (radiation - heat storage), **latent heat (ET)** and sensible heat fluxes (Lower)

Relationship of annual *ET* to annual available energy

Data from PASOH by our Kyoto Univ.

Available energy allocates high portion to *ET*

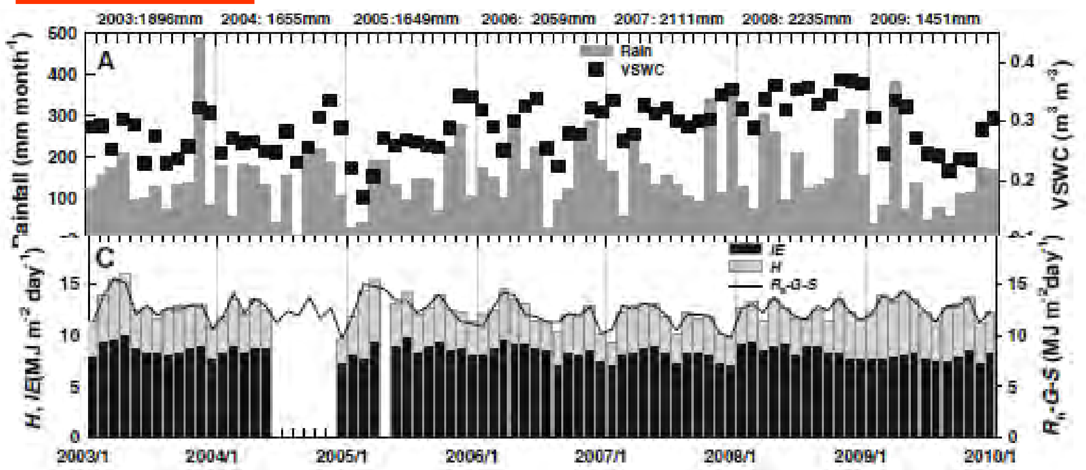
Kosugi et al., J. For. Res. 17, 2012

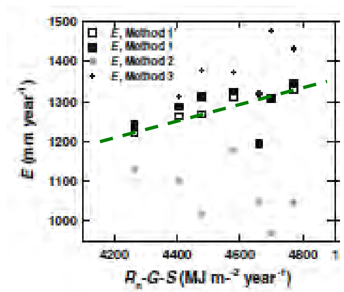
DISCUSSION

Tropical forest

Malaysia

Please see our 7 year Observation on H_2O & CO_2 exchange in Pasoh In Kosugi et al., J. Forest Research 17, 2012





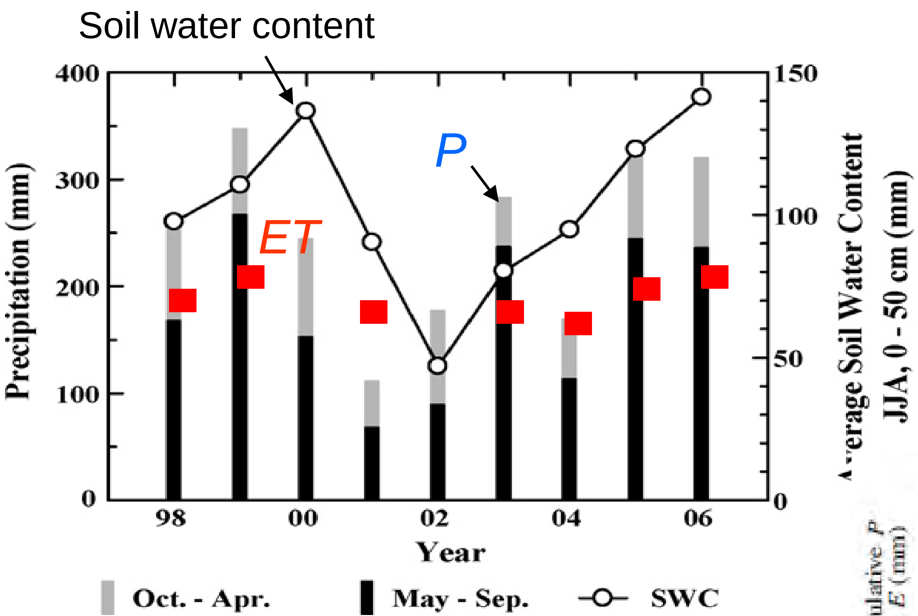
Monthly P and Soil water (Upper), and available energy (radiation - heat storage), latent heat (ET) and sensible heat fluxes (Lower)

Relationship of annual *ET* to annual available energy

Forest ET in tropics is constant and slightly larger in dry and sunny seasons

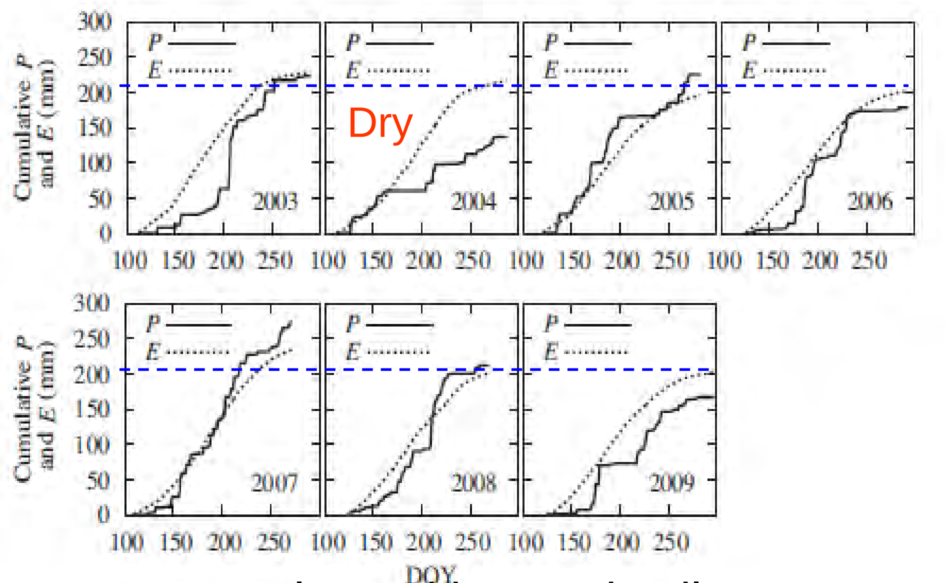
DISCUSSION

Boreal forest



Annual *ET* with *P* and soil water
in a larch forest, **Siberia**

Ohta T. et al., Agric. For. Meteorol. 148, 2008.



Annual *ET* with *P* and soil water
in a black spruce forest, **Alaska**

Iwata et al., Agric. For. Meteorol.161, 2012

Boreal forest on a permafrost
has a constant *ET*
in a dry year
using frozen-melted water
fallen in the previous year

DISCUSSION Function of forest *ET*

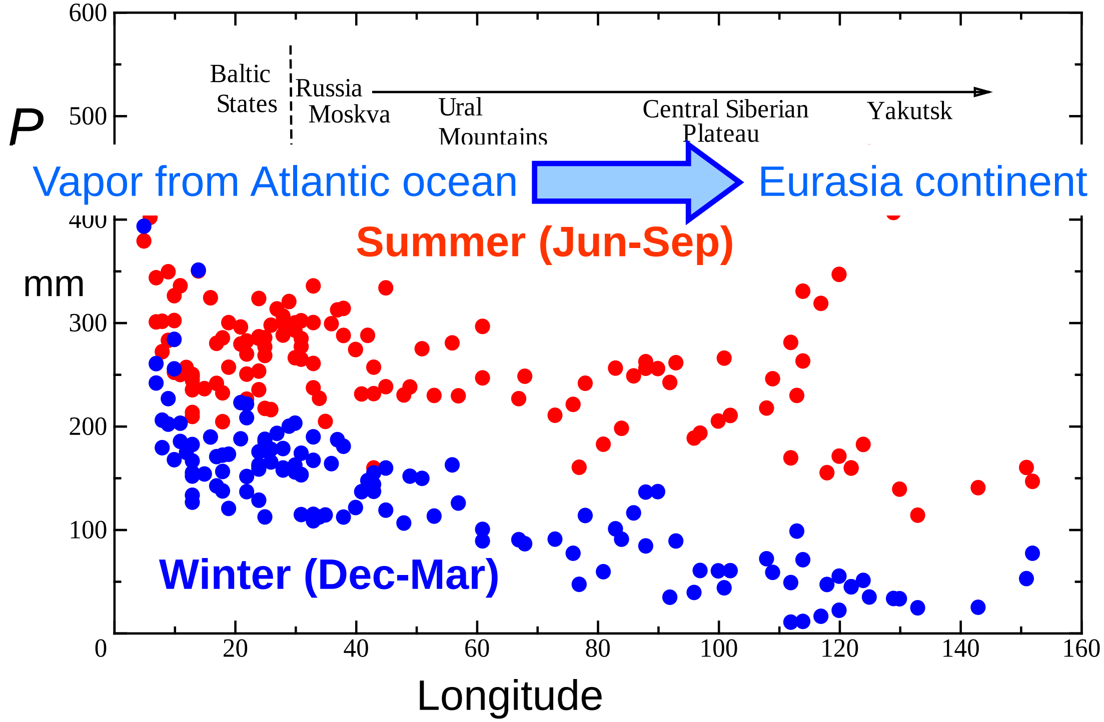
A high dependency of ET on the atmospheric demand with a high resistance against the dryness of soil water is revealed in forest throughout the world

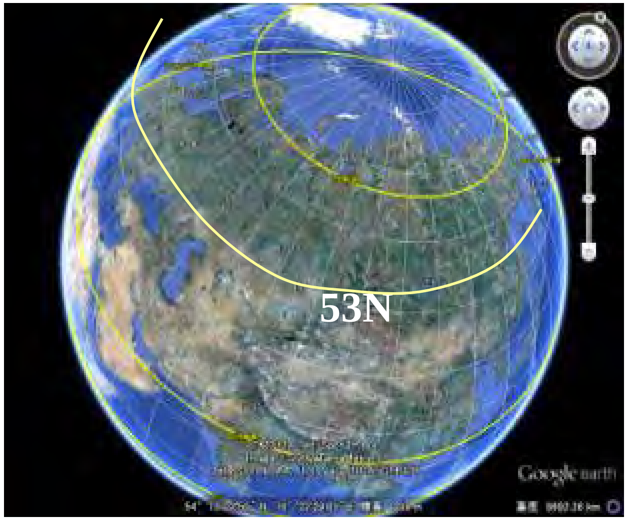
This can be derived from a strong resilience of an individual tree against the severe dry stresses encountered during its long life

In a region, where precipitation comes from EVP in the sea such as islands and peninsulas, forestry with cut is rather desirable for watershed management

Sustainable operation of forestry

DISCUSSION Function of forest *ET*





Precipitation distribution in the latitude of N53 - 70 in Eurasia

Data set by japan Meteorological Agency

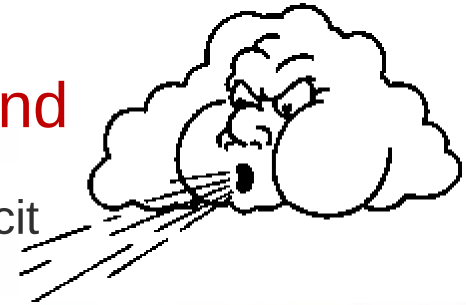
Vapor from Atlantic Ocean is consumed in Europe in winter, but is recycled through the land ET to reach Far East in summer

In a region, where precipitation comes from *ET* in the land surface such as large continents, a large-scale cutting of forest may cause a reduction of P

Although the resilience of forest *ET* is a universal nature, its function is different between **islands** and **continents**

CONCLUSION

Atmospheric demand



Net radiation

Vapor deficit

Penman-Mon
Equation

cr

r_A

Forest *ET* follows the atmospheric demand

Further warming may reduce *ET* by soil dryness

Soil dryness control

Atmos. Demand

0

Soil moisture

Function of *ET* for water is different between islands and continents

Acknowledgement

Continuous catchment observation since 1937
by FFPRI
(Forestry and Forest Products Research Institute)
is highly appreciated.

Thank you