# Response of Vegetation Biophysics to Changing Precipitation in ChiLan Montane Cloud Forest


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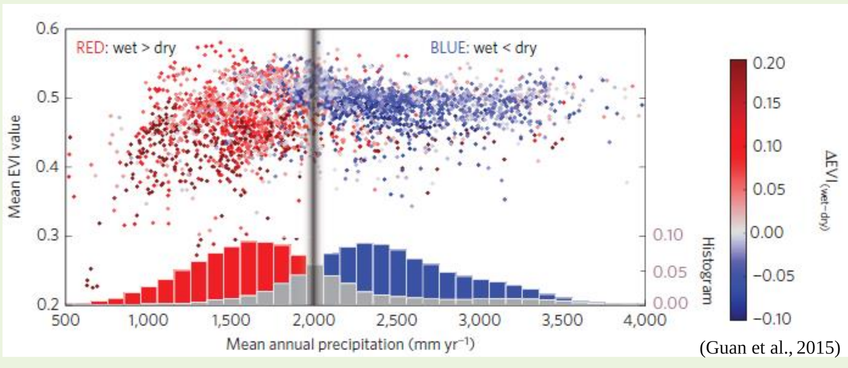
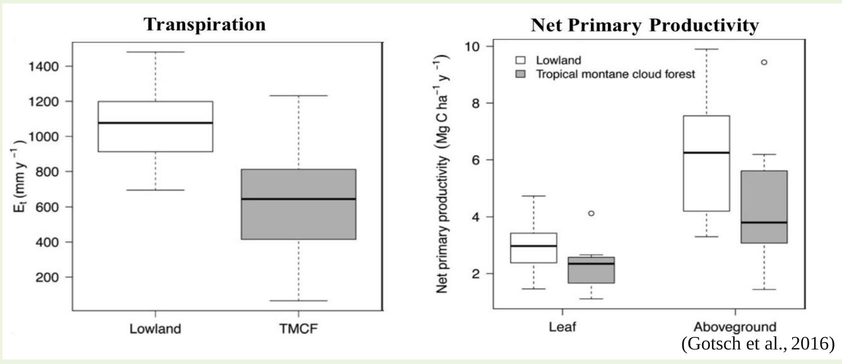
## 1. Introduction

Rainfall is one of the essential factors in affecting the inter-annual variability of vegetation productivities over tropical forests. Among the tropical forests, places with annual rainfall larger than 2000mm, local vegetations does not suffer from water shortage in the dry season. **However, in tropical montane cloud forests, transpiration and productivity are lower than in non-cloud forests through trees in montane cloud forests have more water availability.** A threshold of 2500mm annual rainfall was found in Taiwan, and the regions above this value are not affected by drought because of the long preservation of soil moisture. Our study aims to **compare the water demand between Taiwan's non-cloud forest and montane cloud forest** on both sides of the threshold line in drier conditions and understand the controlling factors for the plant-water relation.

**Question: Does precipitation affect vegetation photosynthesis in montane cloud forests during drier environment?**



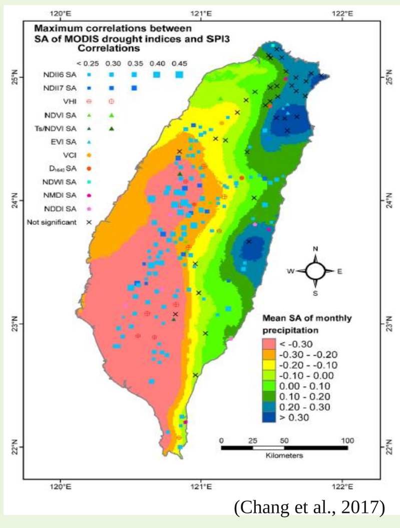




Fig. 1 (left top) Mean annual precipitation versus mean annual EVI (satellite-inferred photosynthetic properties) for global tropical evergreen forest. Color shaded by the values of ΔEVI, whose corresponding histograms are shown at the bottom. **Negative ΔEVI (blue dots) indicate better photosynthetic capacity during dry season**, while positive ΔEVI (red dots) means local vegetation are lack of water. A threshold of 2000mm/yr rainfall could be identified.
Fig. 2 (right top) Comparison of tropical lowland rainforest and montane cloud forest transpiration and net primary productivity (mainly produced from photosynthesis).
Fig. 3 (right) Maximum correlations between satellite indices and the SPI3 (drought index derived by monthly rainfall) for each meteorological station over Taiwan, and mean standardized anomalies of monthly precipitation (background) during 2001−2013.
A **positive–negative trend along the northeast–southwest direction** was observed in the figure. No significant correlation results are mostly shows in northeastern Taiwan especially places where the received annual precipitation > 2500mm.

## 2. Methodology

**Research Time period:** January to April

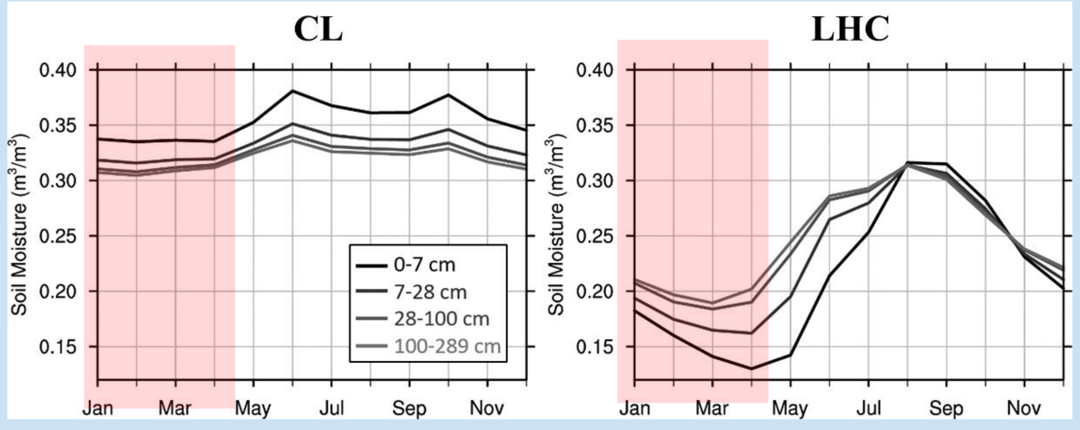



Fig. 4 Soil moisture seasonality in CL and LHC.

Photosynthetic activity begins with transpiration, which drives stomatal opening, and the process obtain water from soil. Both sites have **lower value in soil water from Jan.-Apr. (spring season).**

### Observational Datasets

**1. In-situ flux tower:** observational monthly rainfall data
- ChiLan montane cloud forest (CL): 2008-2011; 2015-2019
- LienHuaChih non-cloud forest (LHC): 2008-2016

**2. Satellite Data:** Enhanced Vegetation Index (EVI)
- from Moderate-resolution Imaging Spectroradiometer (MODIS)proxy for vegetation photosynthetic capacity

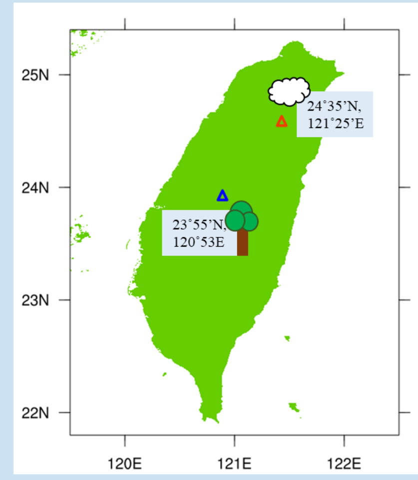



Fig. 5 Map of CL and LHC.

### Model Simulation

**NCAR Community Land Model 5.0 (CLM5.0)**
- Land surface model with atmospheric forcing from observation
- Multiply observational precipitation value by 10% to 150%
- Simulate Transpiration and photosynthesis
- Find impact factors that derive stomatal conductance and thus gas exchange

**Model Experiment Design**

Table. 1 All experiments are categorized two by two for comparison. We adjusted preceding Nov.-Dec. rainfall value as input forcing and then output transpiration and photosynthesis results from model simulation in each experiment. A, B, C category are designed for different purpose.

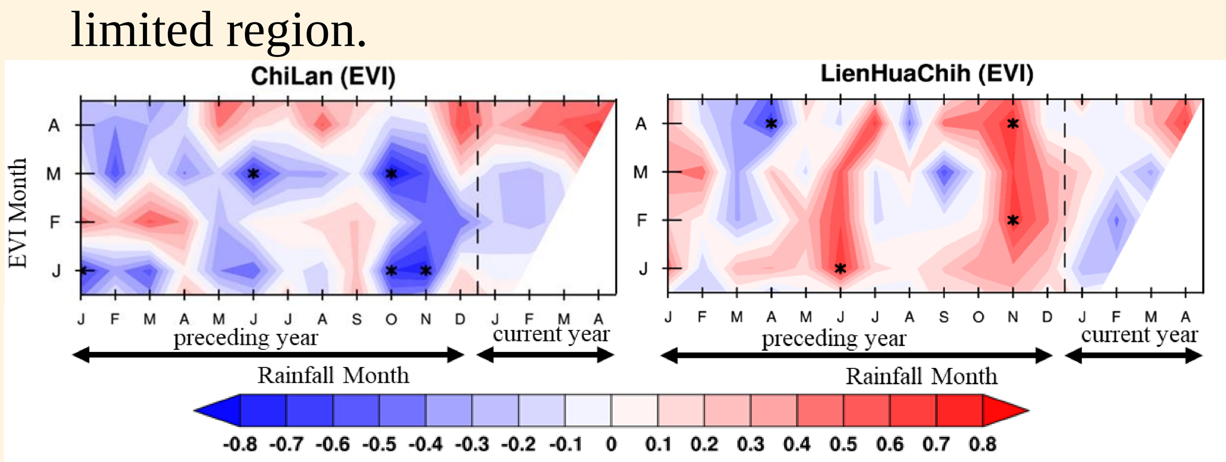
| | Name of experiments | Atmospheric Forcing & Land surface |
|---|---|---|
| A | CL | CL atmosphere & CL land |
| | LHC | LHC atmosphere & LHC land |
| Exchange landtype | | |
| B | LHCatm_CLsurf | LHC atmosphere & CL land |
| | CLatm_LHCsurf | CL atmosphere & LHC land |
| Exchange 11-12 rainfall value | | |
| C | LHCclm_CLsurf | LHC atmosphere (with CL 11-12 rainfall) & CL land |
| | CLclm_LHCsurf | CL atmosphere (with LHC 11-12 rainfall) & LHC land |

A. To validate how the water and carbon flux followed by rainfall change with observational result and then find out the controlling factor for stomata conductance.
B. To identify the dominated characteristic in the vegetation gas exchange process: land type or microclimate?
C. To present the importance of soil water stability affecting transpiration and photosynthesis.

## 3. Result

### Observational Analysis

- Lead-lag relationship between Nov.-Dec. precipitation and Jan.-Apr. EVI.
- CL vegetation is less susceptible to rainfall, while LHC seems to be a water-limited region.



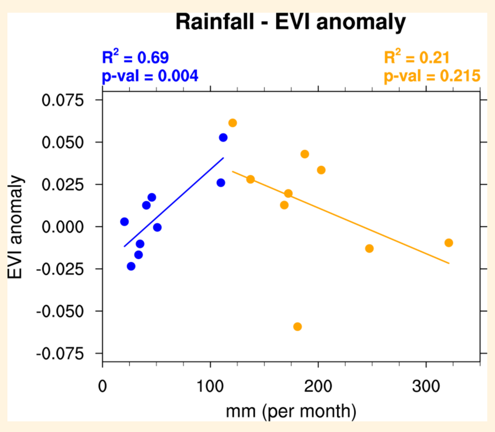




Fig. 6 (left) Correlation coefficients between monthly rainfall and Jan.-Apr. EVI from the preceding year to the current year in (a) CL and (b) LHC. Black dots indicate with significant correlations ($p < 0.05$). The white area is vegetation-leading condition, which are not to be considered in our research.
Fig. 7 (right) Averaged Nov.-Dec. rainfall versus Jan.-Apr. EVI anomaly in CL (orange) and LHC (blue). The lines show linear regression results in each site. EVI changes in LHC is highly related to rainfall. The correlation in CL is not significant.

### Model Simulations

- Similar water demand situation to observational results.
- Microclimate affects more in an ecosystem rather than land type characteristic.
- Vapor pressure deficit (VPD) and Transpiration beta factor (Δβ, ability of water transport from soil water to transpiration) control the stomatal conductance in plant-water relation, which is affected by temperature and soil water respectively.

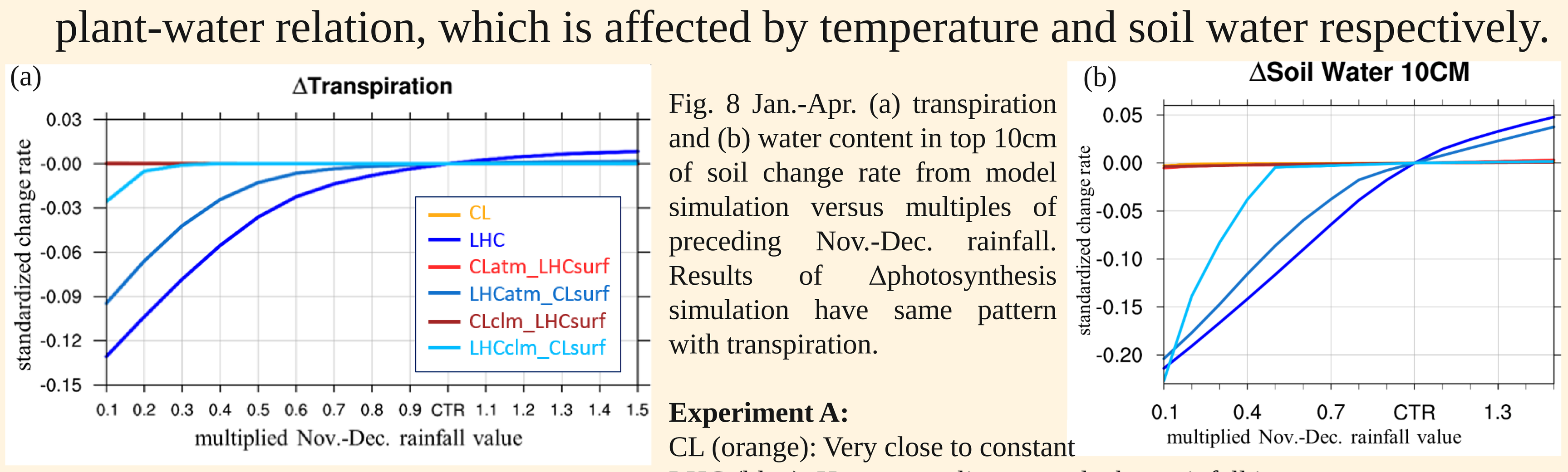
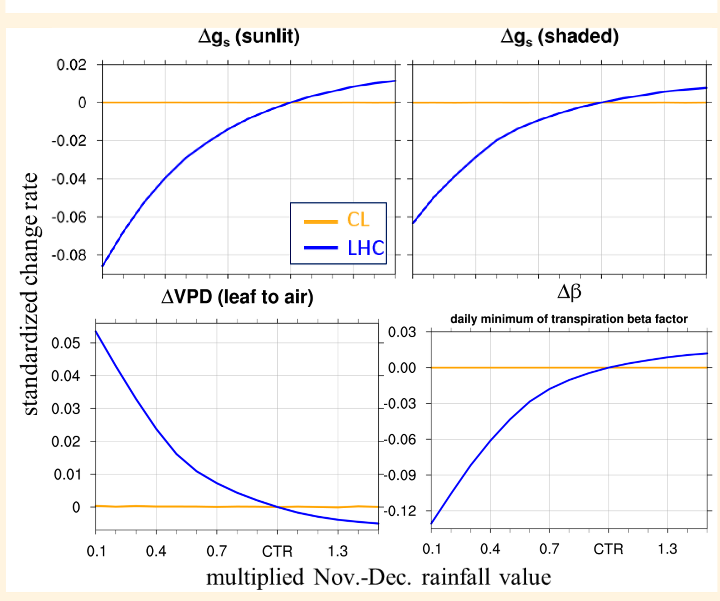



Fig. 8 Jan.-Apr. (a) transpiration and (b) water content in top 10cm of soil change rate from model simulation versus multiples of preceding Nov.-Dec. rainfall. Results of Δphotosynthesis simulation have same pattern with transpiration.




**Experiment A:**
CL (orange): Very close to constant
LHC (blue): Have a non-linear trend when rainfall increase

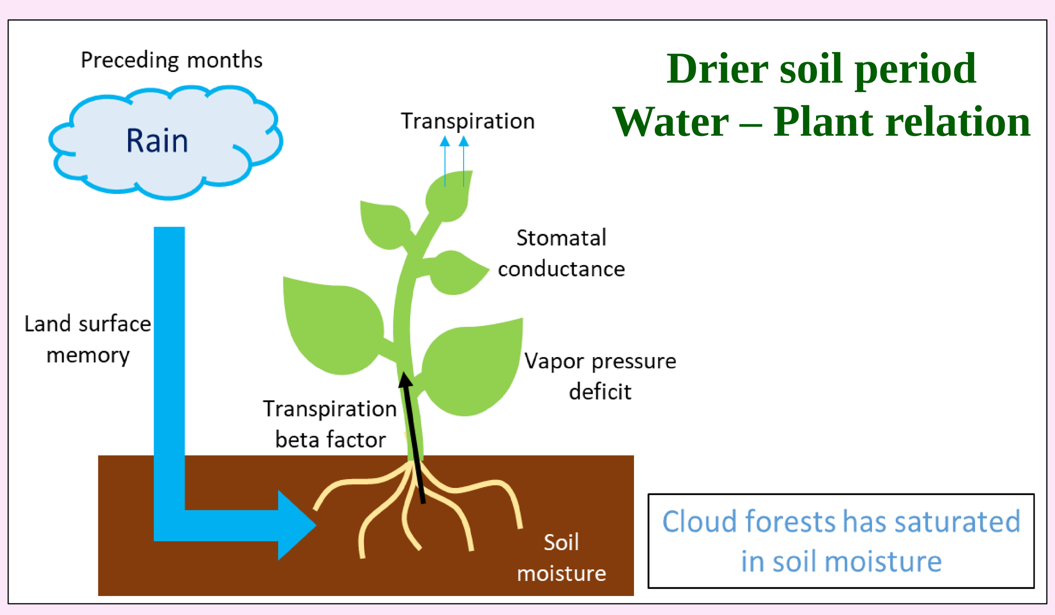
**Experiment B:** Local microclimate dominates the water and carbon exchange process of vegetation in two evergreen forests.

**Experiment C:**
CLclm_LHCsurf (brown): Stable no matter how much rainfall is input..
LHCclm_Clsurf (lightblue): Very dry state at the beginning, resulting in large variation in soil moisture under precipitation changes. A higher amount of rainfall input sharply increases the soil water. Transpiration and photosynthesis tend to be constant after 0.3 times rainfall value, although soil water is still increasing. This infers that **even in non-cloud forests**, subsurface soil water supply to vegetation might be larger than water loss via transpiration and photosynthesis. Thus, **the water and carbon gas change could reach an upper limit, thus transforming into the energy limit condition.**

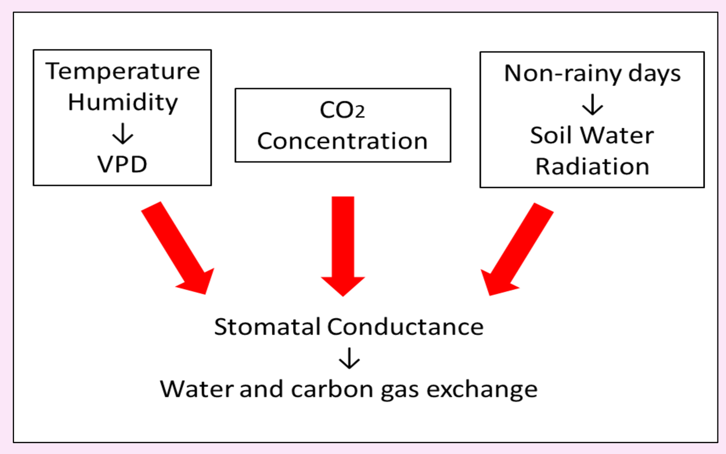
Fig. 9 Stomatal conductance (gs), vapor pressure deficit (VPD) and transpiration beta factor (Δβ) change rate versus multiples of preceding Nov.-Dec. rainfall in experiment A. **In CLM5.0, stomatal conductance was derived by net leaf photosynthesis rate (dominates by beta factor, Δβ), vapor pressure deficit (VPD), and CO2 concentration.** CO2 partial pressure here is constant (not shown). The changes in beta factor complementarity with VPD causing the nonlinear trend in LHC.

## 4. Conclusion

- A lag response with precipitation and vegetation growth because of land surface memory.
- Transpiration beta factor and vapor pressure deficit are functions of stomatal conductance, this could control gas exchange process. The plant water relation is not significantly found in cloud forests because of stable soil water. **→ Montane clouds forests are likely energy-limited even in drier condition.**
- It is unclear whether cloud forests would become essential carbon sinks or vulnerable under multiple climate change factors. Therefore, more idealized model simulations and observational-based data may be needed to clarify the plant water relations in such a special type of forests.




→ Fig. 9 Schematic of plant-water relation in our study.




↑ Fig. 10 Schematic of how the meteorological variables impact stomatal conductance, and then water and carbon fluxes (transpiration and photosynthesis).

## Reference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