運用 TCCIP 高時空氣候重建資料模擬台灣森林植被之動態

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時間: 2023 5/9-5/10　地點: 台大社科院 梁國樹 國際會議廳

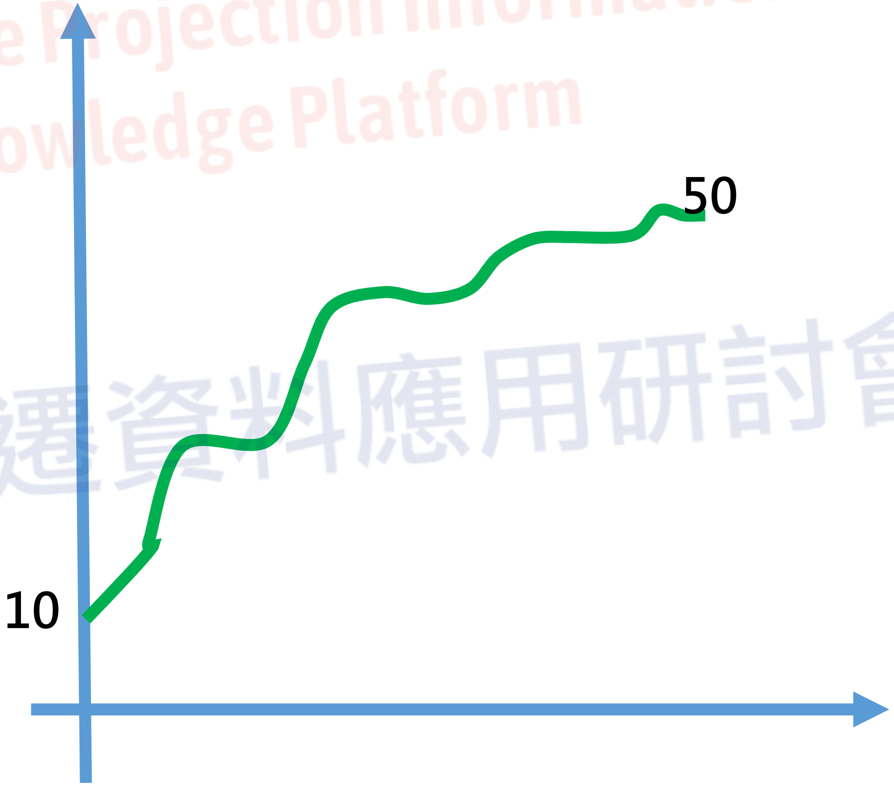
Vegetation Growth and Environmental Disturbances

~10片葉子

2021-06-15

~50片葉子

2021-08-09



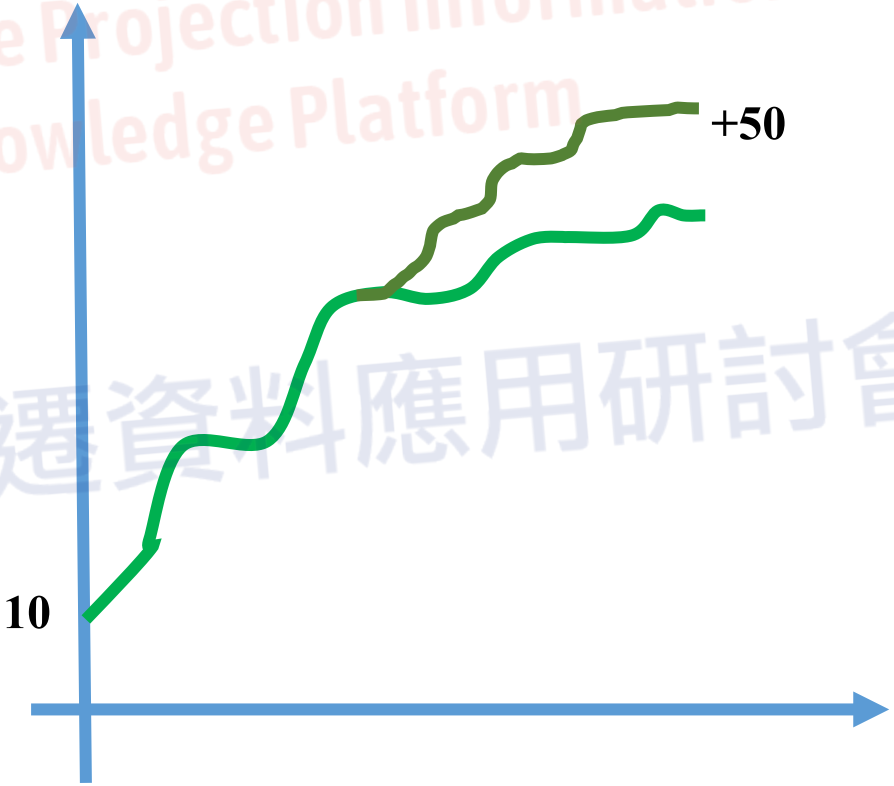
Vegetation Growth and Environmental Disturbances

~10片葉子

2021-06-15

+50片 (施肥 Fertilization)

2021-08-09

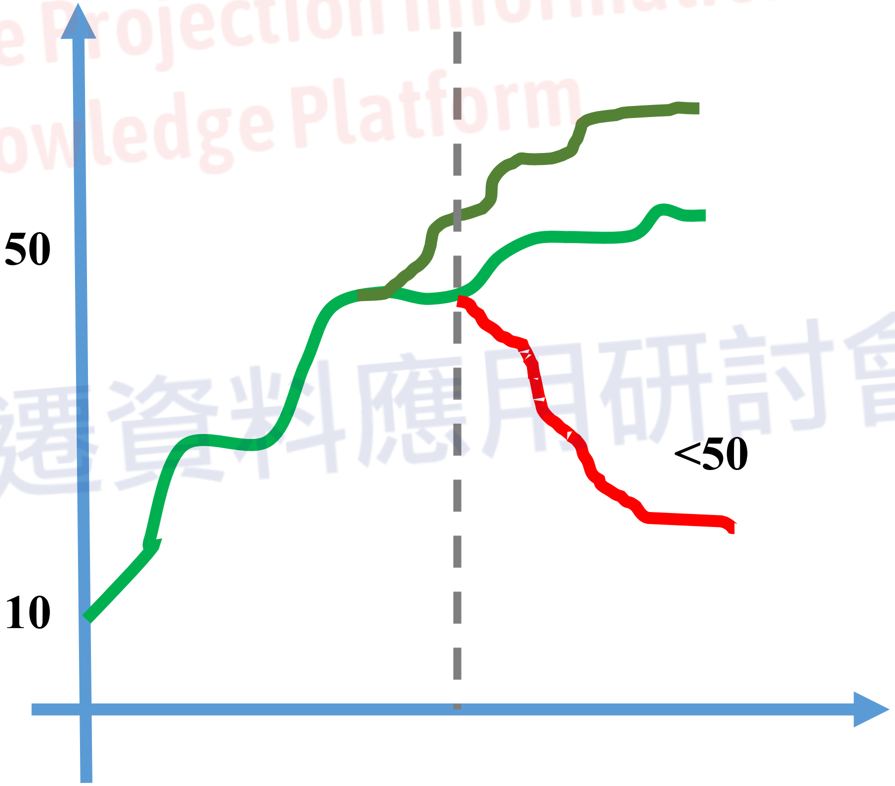


Vegetation Growth and Environmental Disturbances

~50片葉子

乾旱 (Droughts)

<50片葉子



Vegetation Growth and Environmental Disturbances

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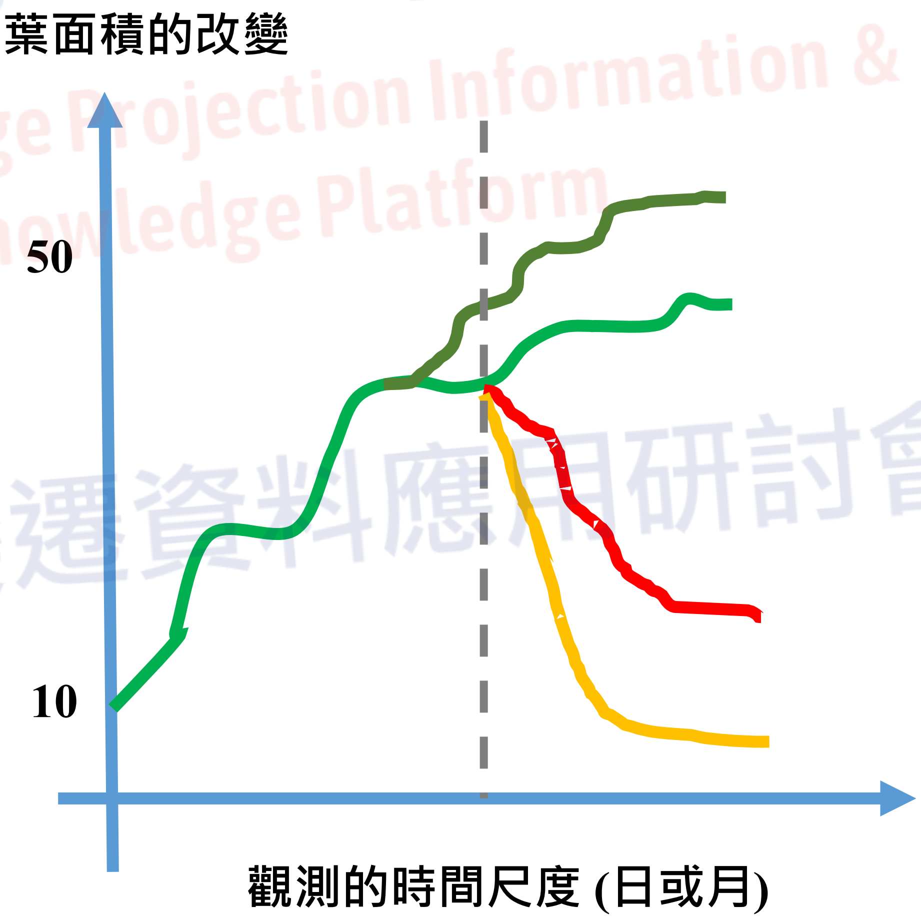
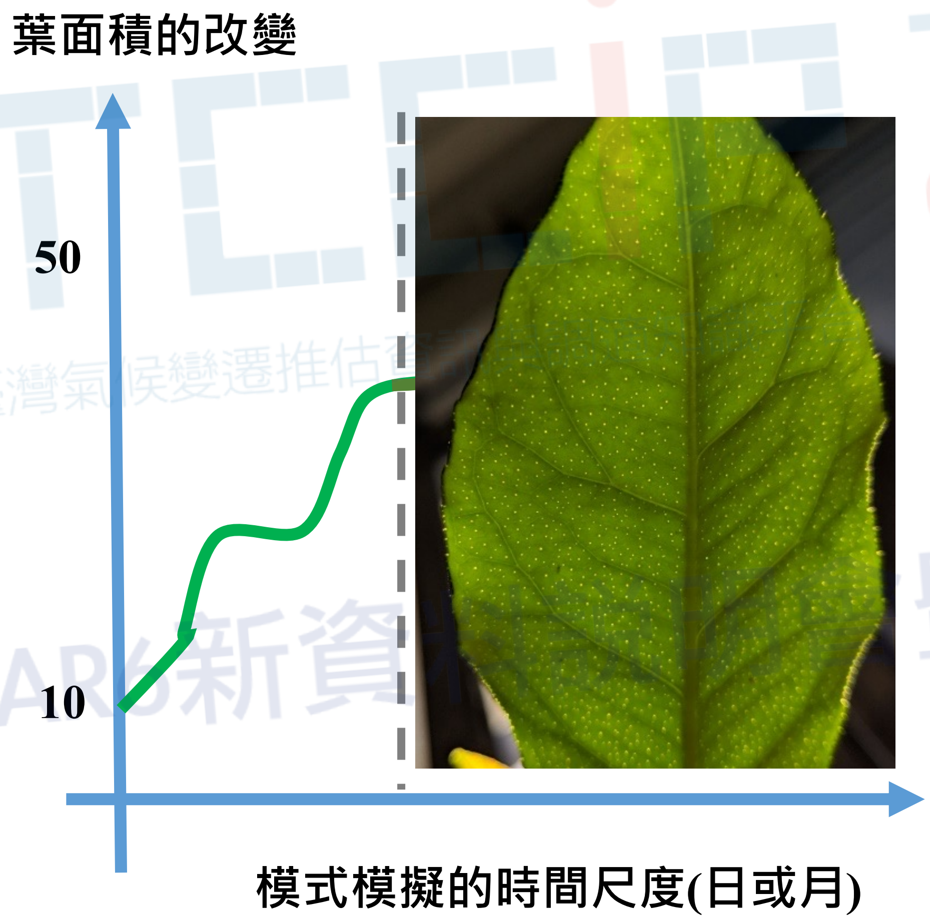
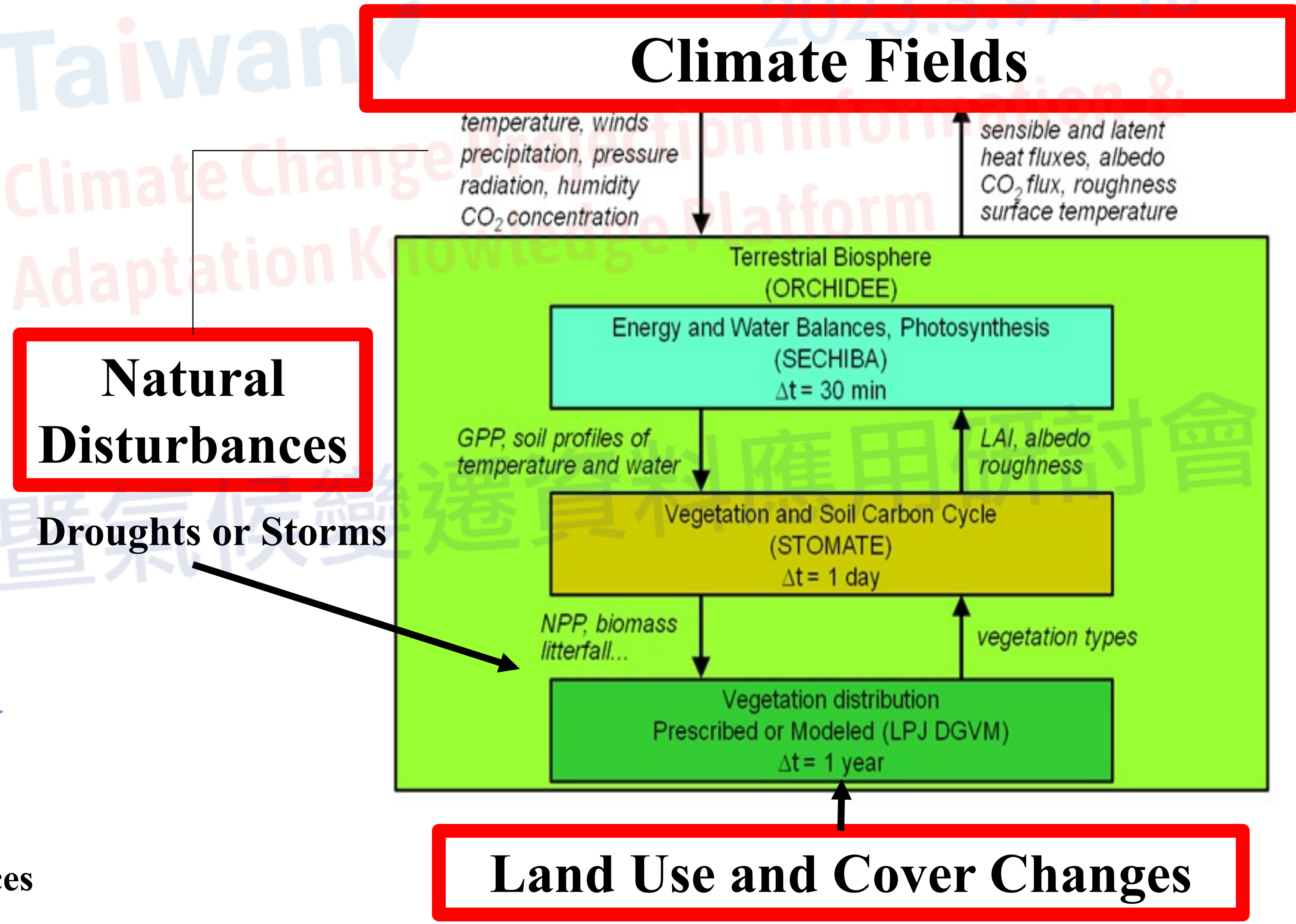
風災 (Wind Damages)



Dynamic Vegetation Model



Vegetation Growth and Environmental Disturbances



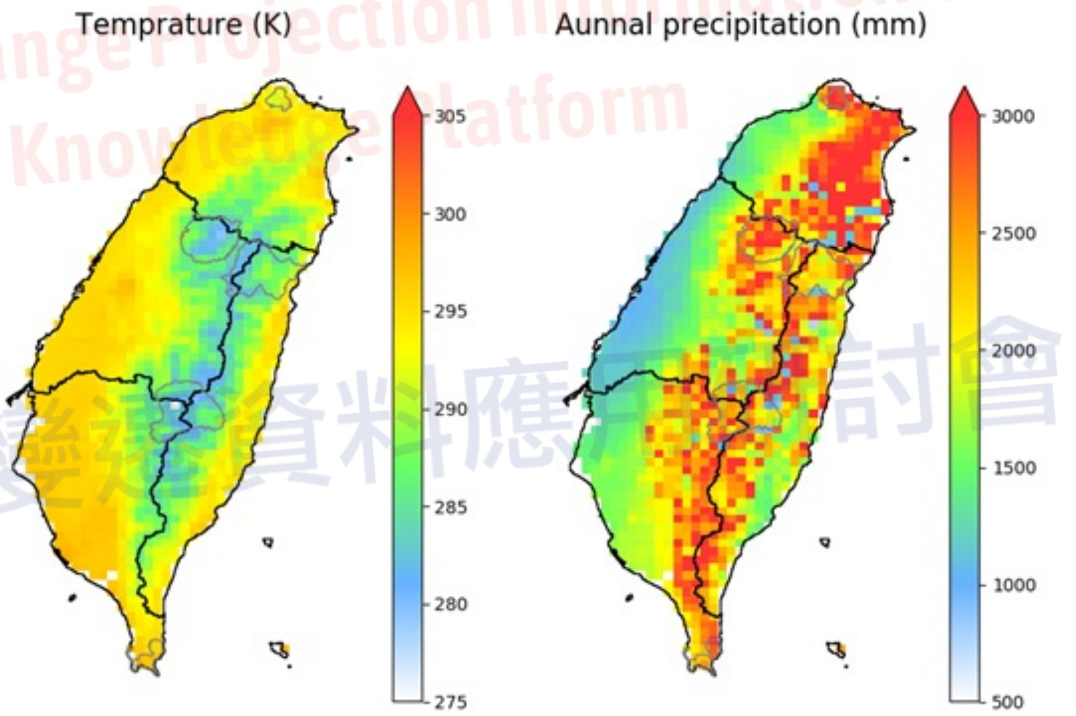
Research Materials

- **Long-term Climate Reconstruction**
- **An Innovative Dynamic Vegetation Model with New Model Features**
- **Long-term Land Use and Land Cover (LULCC) Data**
- **Factorial Numerical Design for the Attribution Study**

Prescribed Atmospheric Conduction (Regional Climate Fields)

The hourly 5 km by 5 km climate fields describing incoming short-wave, long-wave radiation, near-surface pressure, near-surface specific humidity, surface air temperature, and surface wind speeds.

Taiwan Climate Change Projection Information and Adaptation Knowledge Platform project (TCCIP) and Central Weather Bureau (CWB).



1980 to 2007 (TCCIP 鄭兆尊 博士) 2008 to 2017 (CWB 洪景山 主任)

Wind throw module developnment

Very Strong Wind

Overturning

Canopy structure, stand scale

Empirical term for root resistance, canopy properties, aero-dynamic

Streamlining, aero-dynamic

Canopy structure, landscape scale

$$CWS_{ov} = \left(\frac{1}{\kappa D}\right)\left(\frac{C_{reg}\ SW}{\rho G d}\right)^{\frac{1}{2}} \ln\left(\frac{h-d}{z_0}\right)\left(\frac{1}{f_{edge}}\right)^{\frac{1}{2}}$$

Update Tree Mortality

Stem breakage

Canopy structure, stand scale

Canopy properties, aero-dynamic

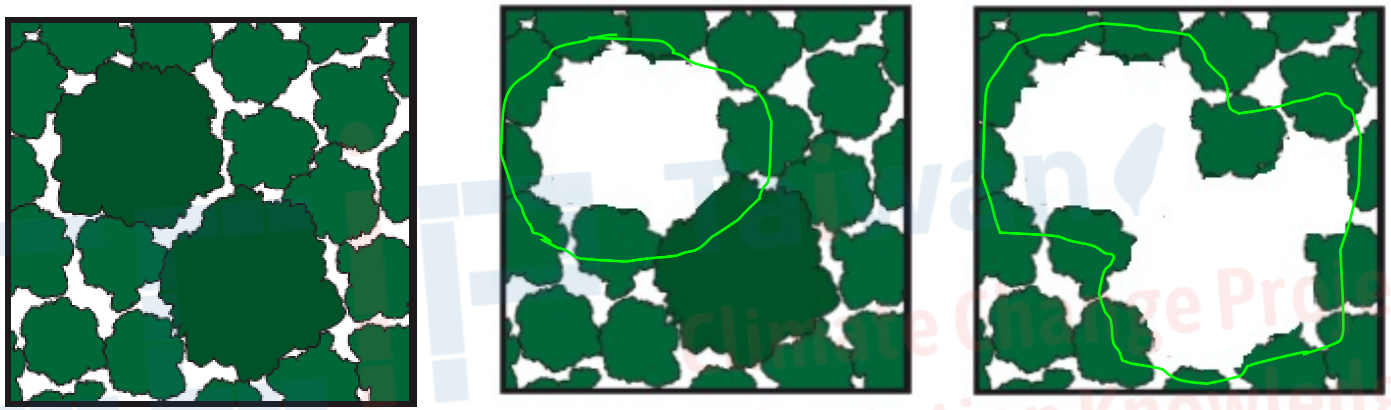
Streamlining, aero-dynamic

Canopy structure, landscape scale

$$CWS_{bk} = \left(\frac{1}{\kappa D}\right)\left(\frac{\frac{\pi}{32} f_{knot} MOR\ diam^3}{\rho G(d-1.3)}\right)^{\frac{1}{2}} \ln\left(\frac{h-d}{z_0}\right)\left(\frac{1}{f_{edge}}\right)^{\frac{1}{2}}$$

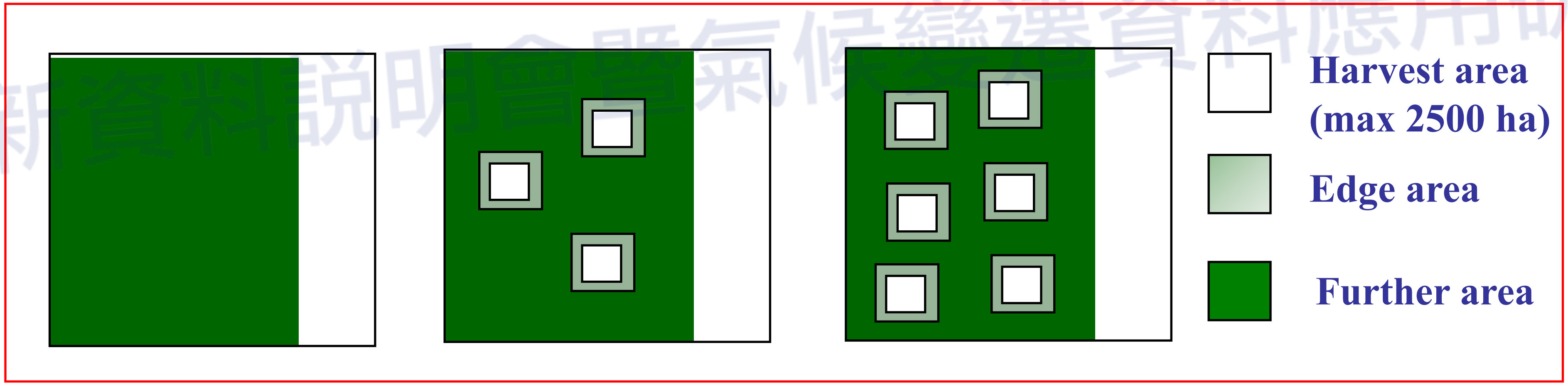
Chen *et al.*, 2018

REAL FORESTS



before 2001 | 2002 & 2003 | 2005

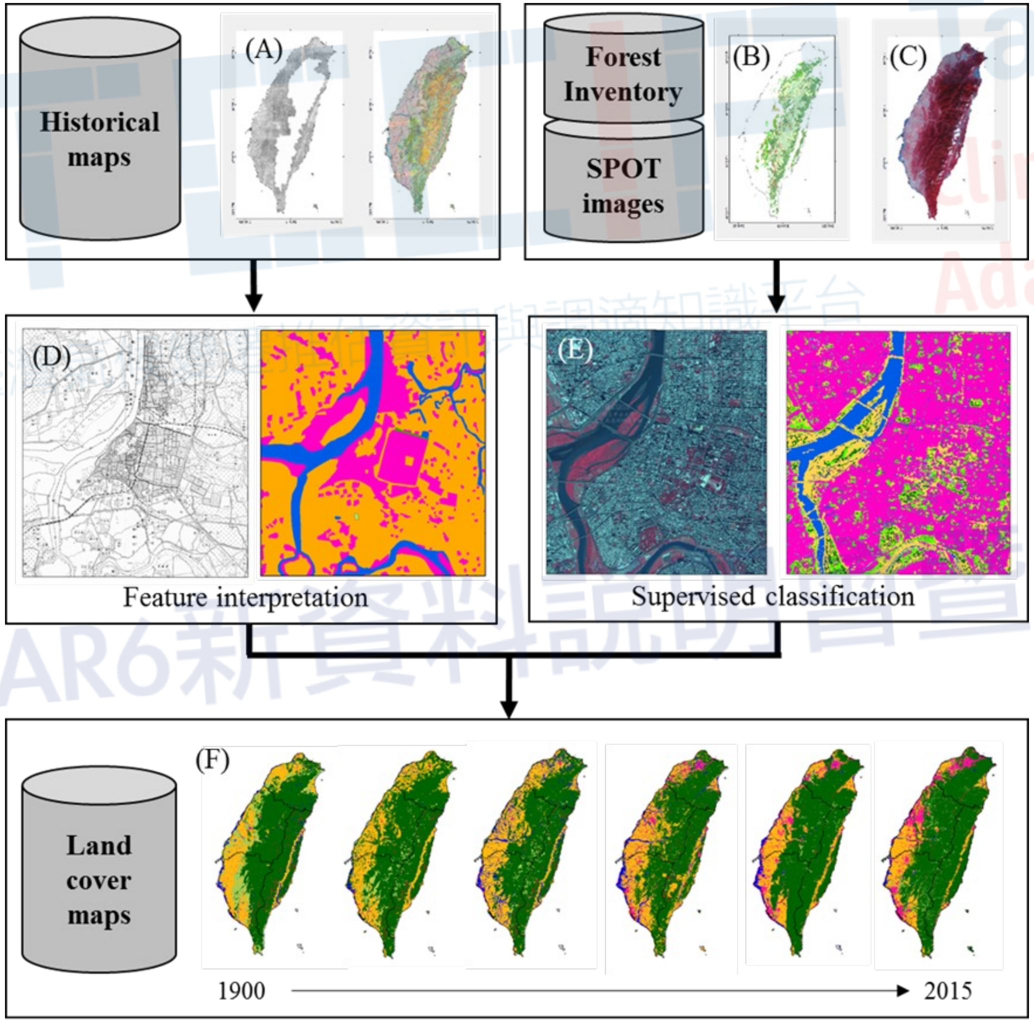
FORESTS in the MODEL

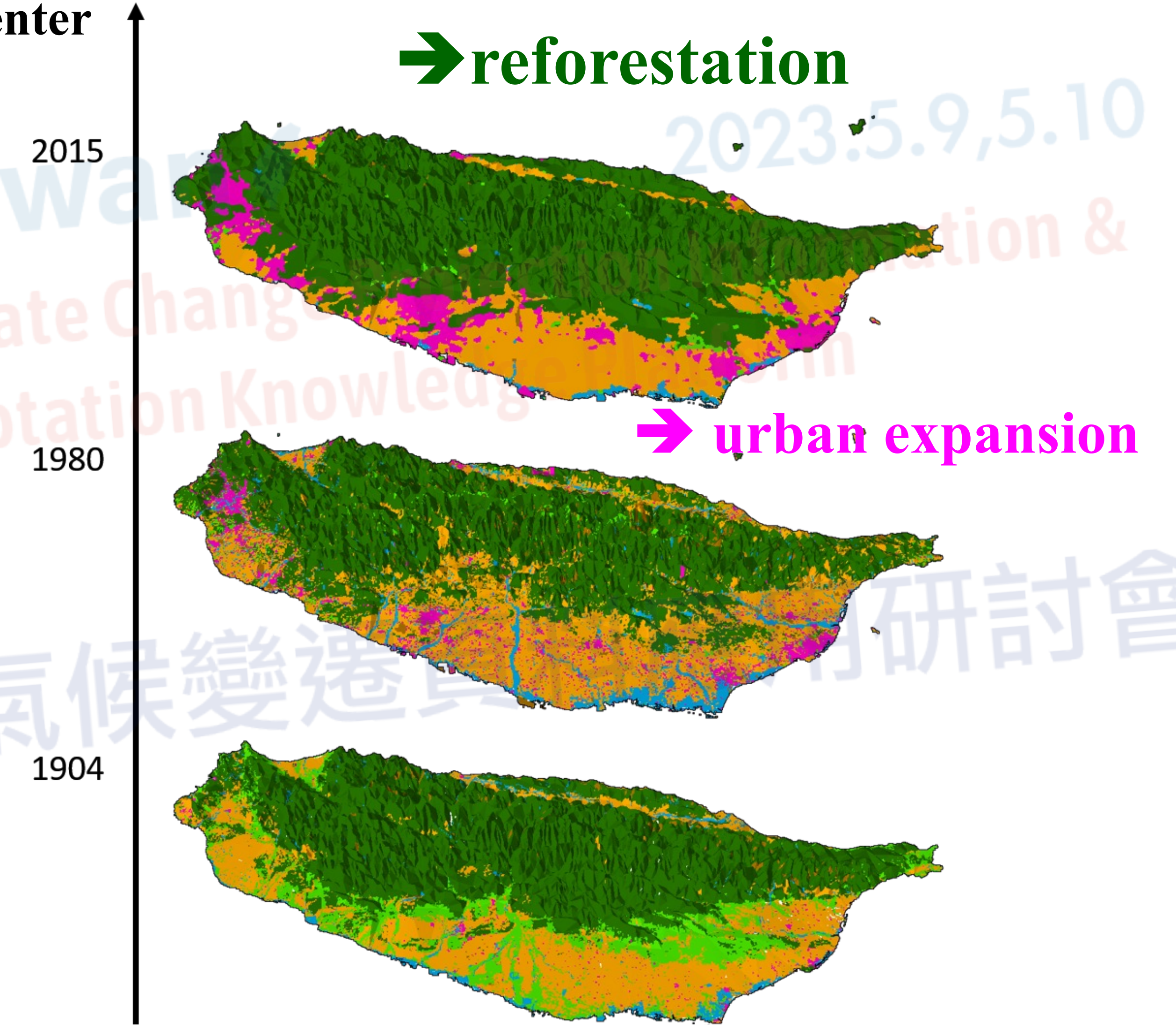


Chen *et al.*, 2018

Land Cover Reconstruction from 1904 to Present day

- **Historical Maps from Academia Sinica GIS Center**
- **SPOT Satellite Images from NCU-CSRSR**





A New Reconstitution of Taiwan's Land Cover Changes and Uncertainty between 1904 and 2015 is Presented and Opened to the Public (**doi:10.5281/zenodo.1307309**). (Chen et al., 2019.)

Experimental Design

1600 **Spin-up**

EXP-T0

300 years

Cold Climate (1979)

LULCC
(Fixed @ 1901)

1900 **Transient**

EXP-T1

Cyclic Climate*

(1979 – 1994)

REAL LULCC Forcing after 1900

1980 **Control**

EXP-T2

Factorial Simulations

EXP-T3

Real Climate

Present day

REAL LULCC + REAL CO_2 level

EXP-T3A: LULCC (Fixed at 1980)

EXP-T3B: CO_2 (Fixed at 1980)

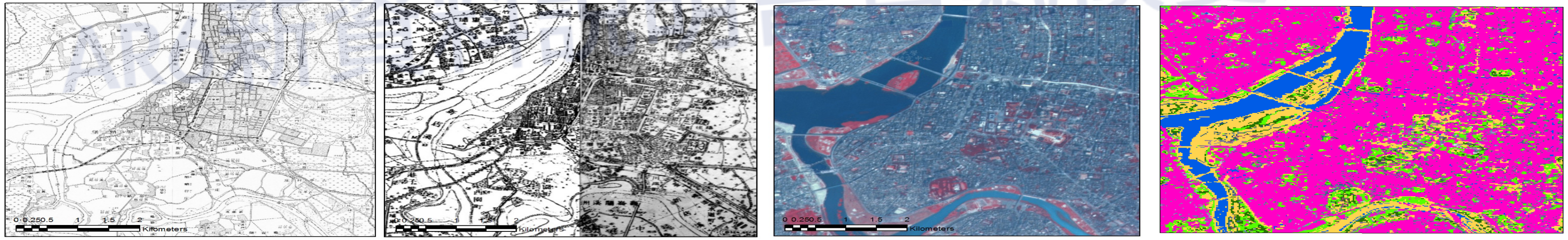
EXP-T3C: No Windthrow

Future Simulations

EXP-T4

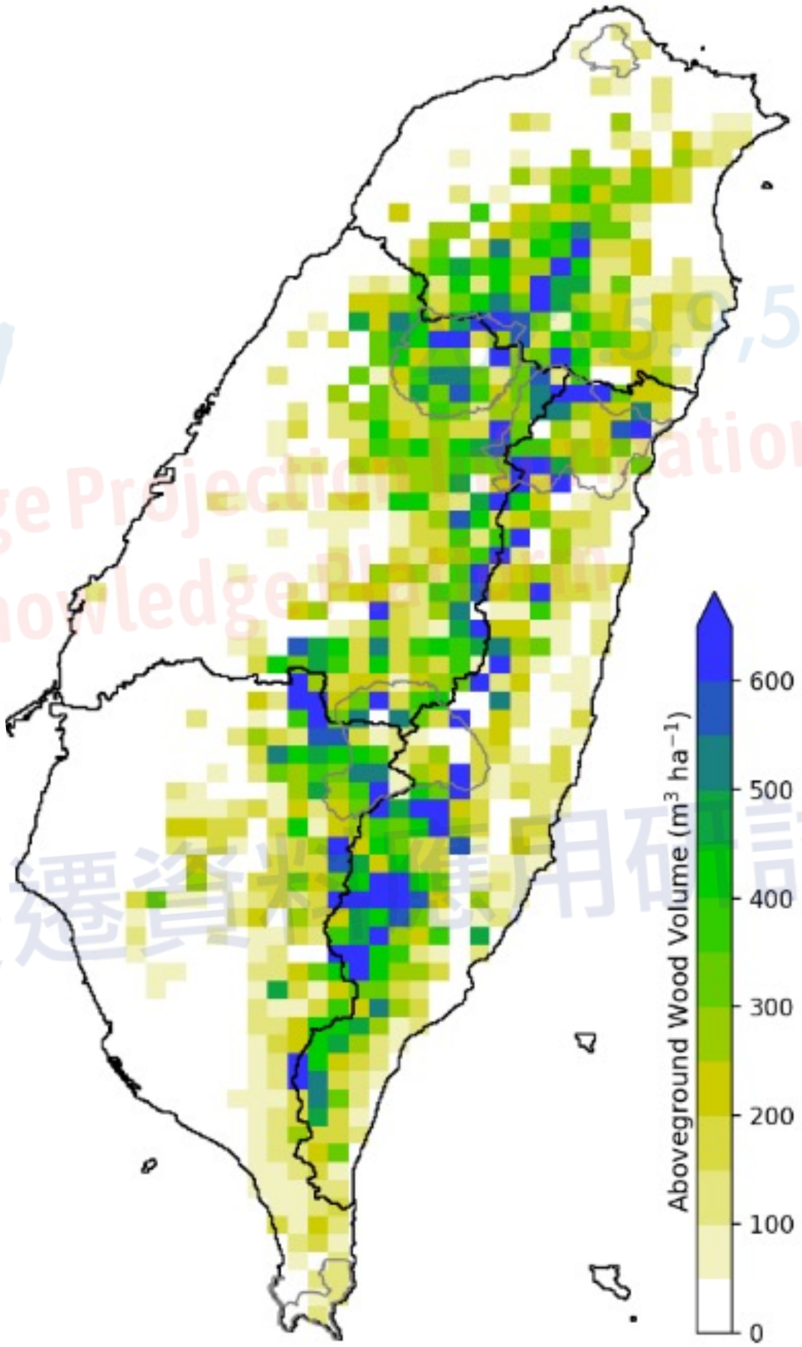
進行中

SSPs
2^oC / 4^oC

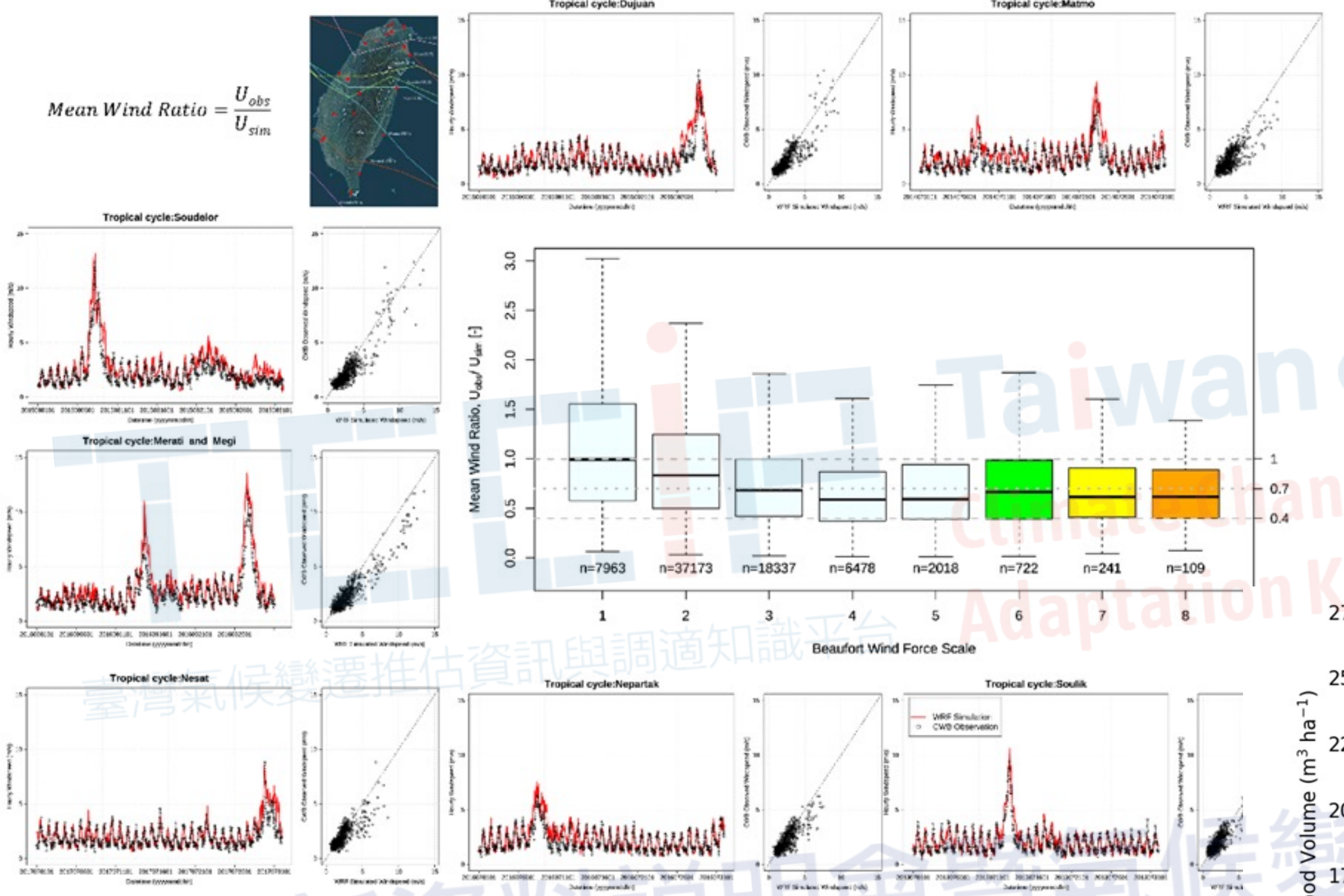


***Hsu and Chen 2011; Chen et al., 2022**

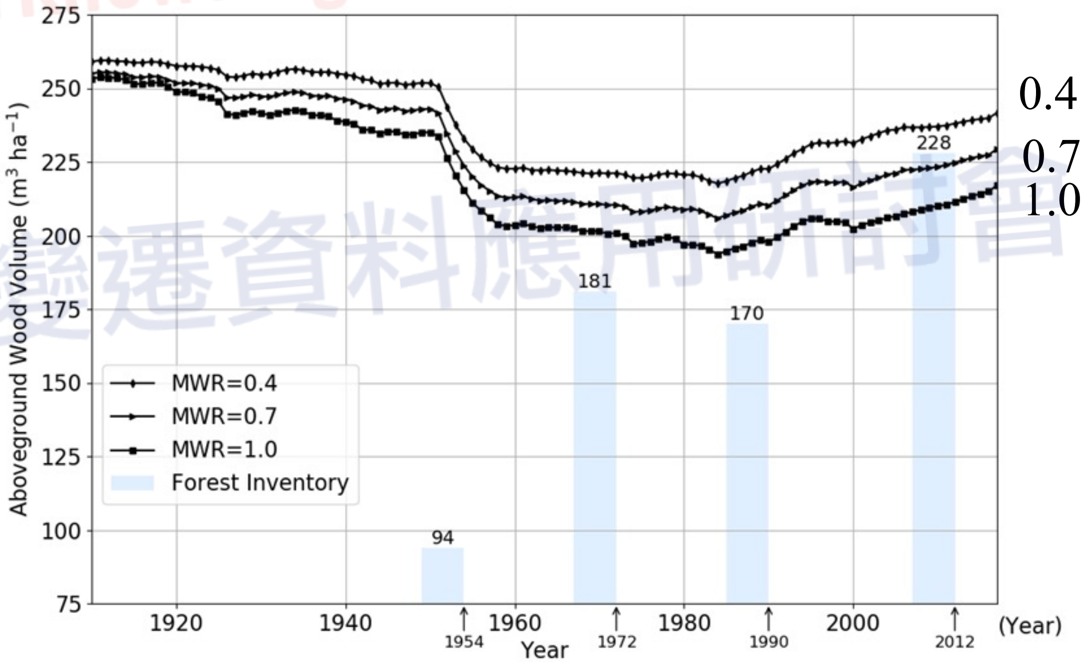
Result-
Model Tuning & Evaluation



Model Tuning

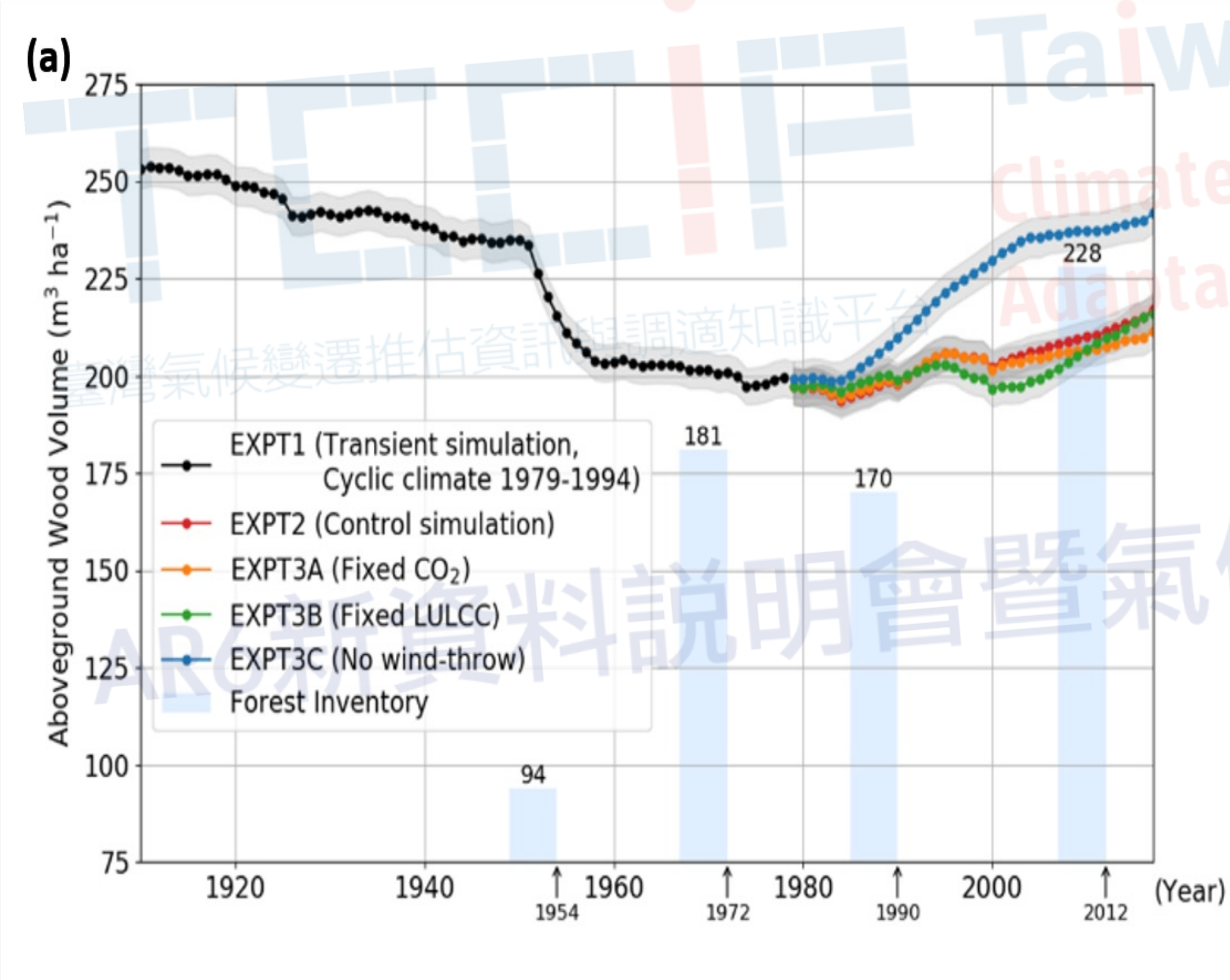


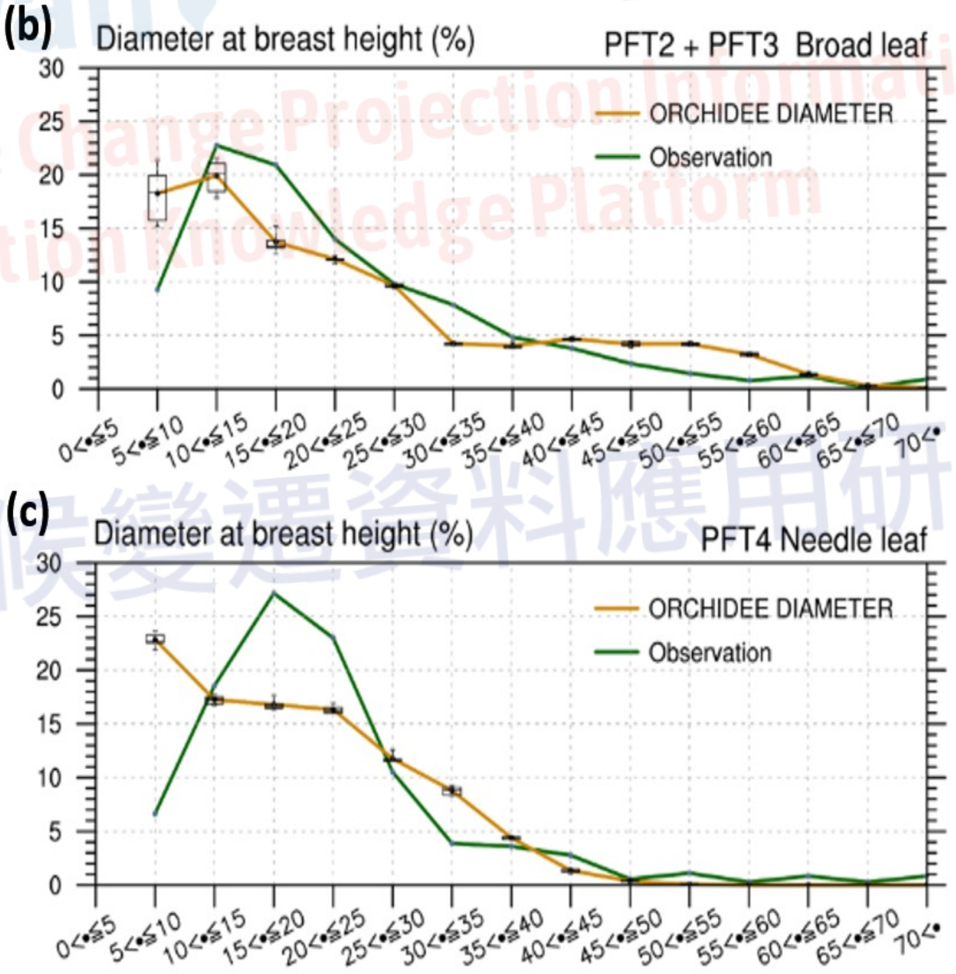
Mean Wind Ratio (MWR)
$=U_{obs}/U_{sim\ (TCCIP)}$



The statistics for the hourly 10m wind speeds observed by CWB stations and simulated by WRF for eight selected extreme events. The red and circled black lines represented the medan (50%) of all observed wind speeds and the nearest simultaneous WRF simulated wind speeds.

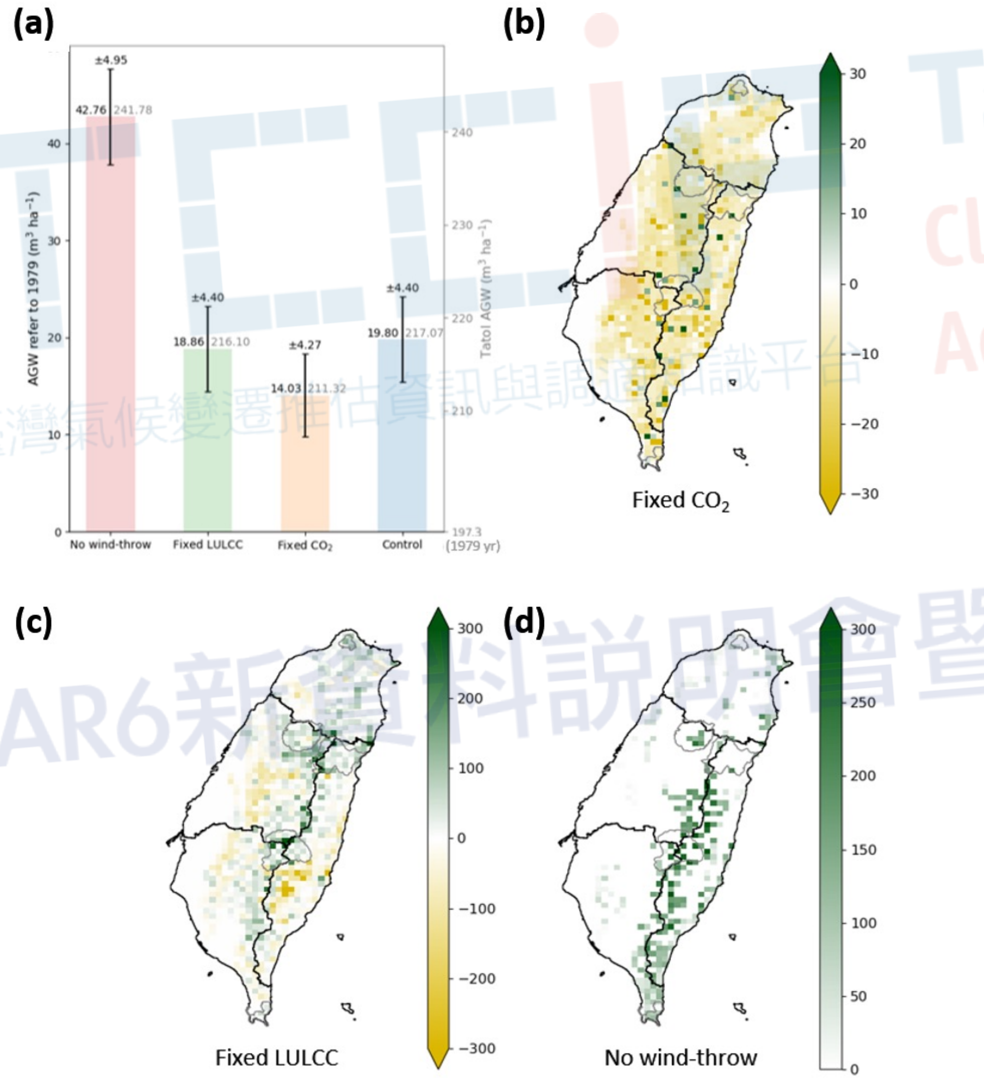
Model-simulated AGW and Forest Inventory





DBH

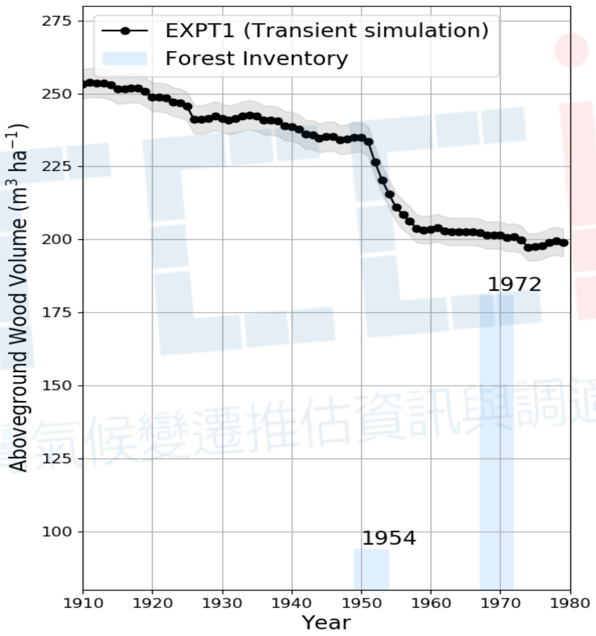
Attribute Changes in Forest Biomass to Environmental Disturbances

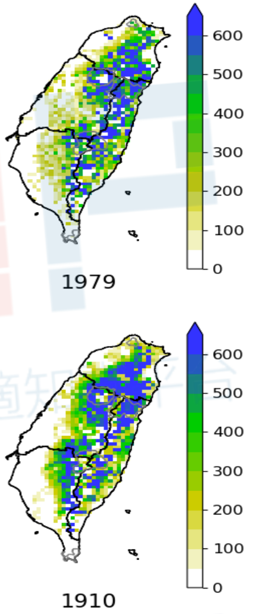


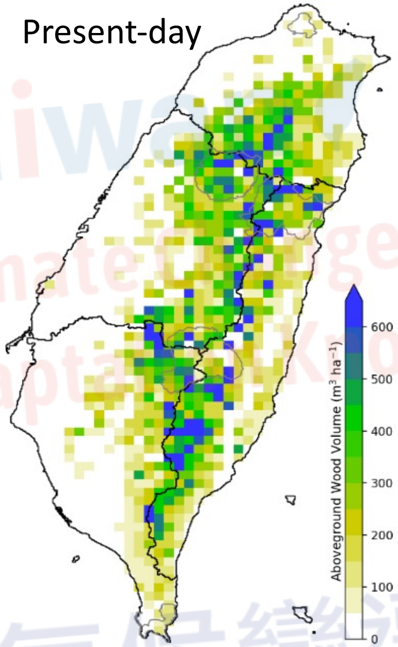
- **Tropical Cyclones Decreased Forest Biomass more than the Combined Effect of Land Cover Change and CO_2 Fertilization, and its Associated Climate Changes**

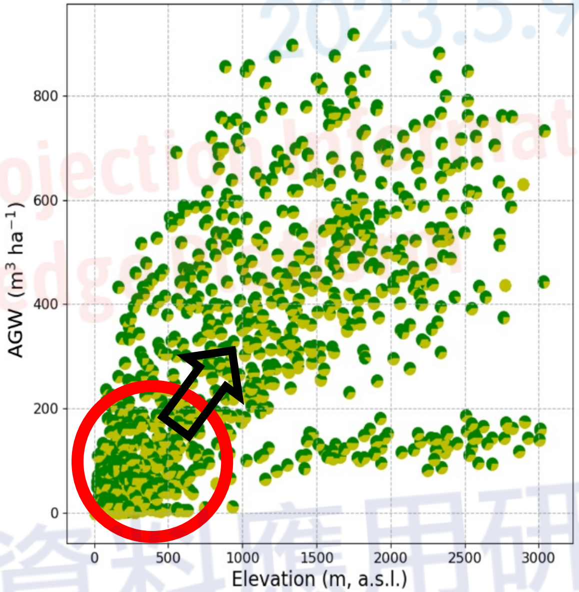
- **Models might Largely Overestimate the Forest Biomass in Regions Prone to Frequent Tropical Cyclones without Considering Wind Disturbances**

Discussion- Present-day Forest Biomass









Region	Area of young forests in this region x 10^2 (ha)	Average AGW for young forests (m^3 ha^{-1})	Average AGW for the other forests (m^3 ha^{-1})	Yong forests percentage (%)	Potential increase (m^3 ha^{-1})
Lowlands (< 500m)	6,700	75.5	109.9	47.4	16.2
Low Elevation Mountains (500 ~ 800 m)	3,000	124.0	173.4	39.7	19.7

Vulnerabilities of the Biomass Distribution

- The factorial simulation experiment suggests that over the past 40 years, **the frequent occurrence of tropical cyclones has had a more substantial effect on the AGW than the combined effects of land cover change and CO_2 fertilization, and the associated climate change**. Even at the national level, a handful of tropical cyclones could offset the impact of decades of afforestation and forest protection programs and the effect of enhanced forest growth due to changing environmental conditions. Losses in biomass following the passage of intense tropical cyclones have been well documented (Lin et al., 2003; Lin et al., 2011; Uriarte et al., 2019), although a bias towards studying the most intensive tropical cyclones (class 3 and up; Lin et al., 2020) has resulted in a limited understanding of how forests in storm-prone regions respond to the more frequent passage of lower intensity tropical cyclones.
- **Due to climatic warming, cyclone intensity is predicted to increase, and storm tracks are projected to shift poleward** (Mizuta et al., 2017; Tsou et al., 2016; Yin, 2005), especially in temperate climate zones. Moreover, the translation speed of tropical cyclones has also been slowing down, which could be associated with increased local rainfall and storm-induced damage (Kossin, 2018). Therefore, **more intense storms are expected to decrease the AGW of Taiwan's forests**. On the other hand, suppose the storm tracks move northward and thus reduce the frequency of cyclones making landfall in Taiwan. In that case, the forest biomass is expected to increase in Taiwan. Still, it will likely **decrease further northward, where future storms will make landfall.**

Model limitations

- **Nitrogen (N) and phosphorous (P) cycling** are not accounted for in ORCHIDEE r4262. However, nutrient cycling and nutrient limitations may play an important role in tree growth in (sub)-tropical forest biomes (Houlton et al., 2008). The abundance of dissolved inorganic nitrogen in the river discharge in Taiwan (Chang et al., 2020; Huang et al., 2016) suggests that nitrogen is no longer a factor limiting plant growth over large areas of Taiwan. The primary source of this nitrogen is likely to be atmospheric deposition from mainland China, local industry, and household emissions of between 0.8 and 20 kg N ha^{-1} yr^{-1} (Zhao et al., 2015). **Suppose atmospheric deposition continues to increase in the future**. In that case, nitrogen saturation in the soil may lead to a decline in forest growth (Aber et al., 1999, 2003).
- The ideal simulation would account for **both natural and anthropogenic disturbances and the direct and indirect effects of a changing climate** (McDowell et al., 2020). In this study, the most critical drivers in determining the growth of Taiwan forests were assumed to be related to the land cover change, unmanaged forests, storm damage, and CO_2 fertilization, and the associated climate change. **Fire disturbance, which could, under future climatic conditions, become a substantial disturbance in Taiwan**, was not accounted for.
- Future versions of the ORCHIDEE model are expected to be capable of accounting for fire, drought, floods, windstorms, insect outbreaks, land cover changes, forest management, and the interaction between these disturbances. In this respect, model developments may outrun the empirical evidence, and modelers will soon need datasets that can be used to evaluate the impact of individual disturbances and their interactions.

Summary

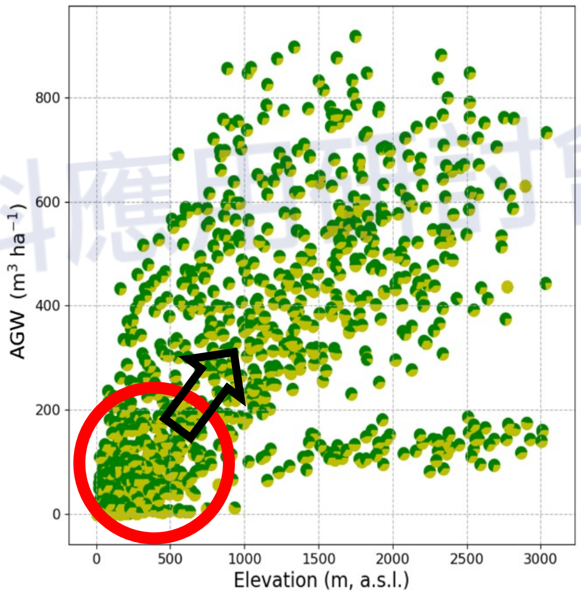
- Forest biomass is one of the main carbon pools of terrestrial ecosystems. Its storage capacity is, however, vulnerable to climate change and anthropogenic and natural disturbances.
- In this study, simulation experiments were used to attribute the impact of **tropical cyclones, land use and land cover change, and increasing atmospheric CO_2 concentrations** on the forest biomass in Taiwan.
- The simulation experiments were possible thanks to a recent century-long country-specific **land cover reconstruction**, recent country-specific **climate reconstructions** (from TCCIP & CWB), and the recently developed model capability to simulate the effects of wind storms on forest biomass.
- The studies show that **wind disturbance strongly affects carbon sequestration rates**; in the absence of wind disturbances, **the annual sequestration rate would double compared to the present-day rate**, including wind disturbances. In order words, not considering wind disturbances might largely overestimate the forest biomass in regions prone to frequent tropical cyclones, of which some reach typhoon strength.

SDG Actions

15 LIFE ON LAND

The present-day global average AGW forest biomass (volume of growing stock) **is 137 $m^3\ ha^{-1}$ and 100 $m^3\ ha^{-1}$ for Asia** (FAO, 2020). The observed forest biomass for Taiwanese forests was 211 ±4 $m^3\ ha^{-1}$ in 2012 and simulated to be 217 ±4 $m^3\ ha^{-1}$ in 2017. The AGW in Taiwan is therefore similar to Japan's (170 $m^3\ ha^{-1}$), around 2 to 3 times the values reported for nearby countries such as China (85 $m^3\ ha^{-1}$), Korea (79 $m^3\ ha^{-1}$) (Tomppo et al., 2010), or the nearby Chinese province of Fujian (87 $m^3\ ha^{-1}$; Xu et al., 2019).

Under the assumption of keeping the present-day forest coverage but letting the young forests (stands age below 30 years reported in the fourth national forest inventory) reach the average biomass for the other forests observed in the same region with a similar climate background. **It would increase the average AGW by about 16 $m^3\ ha^{-1}$ and 20 $m^3\ ha^{-1}$ for lowlands and low elevation mountains**, respectively



2 ZERO HUNGER

調整林業政策，淺山林下經濟的養成與相關經濟活動
農林混合：香菇產業、咖啡產業、山蔬 (林試驗所 南投蓮華池)
平地森林：休憩、螢火蟲帶動觀光農業 (大農大富平地森林)

17 PARTNERSHIPS FOR THE GOALS

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References & Acknowledgements

Plant growth and climate change, J.I.L. Morrison, M.D. Morecroft (Eds.) Blackwell Publishing Oxford, UK (**2006**) 232 pp.

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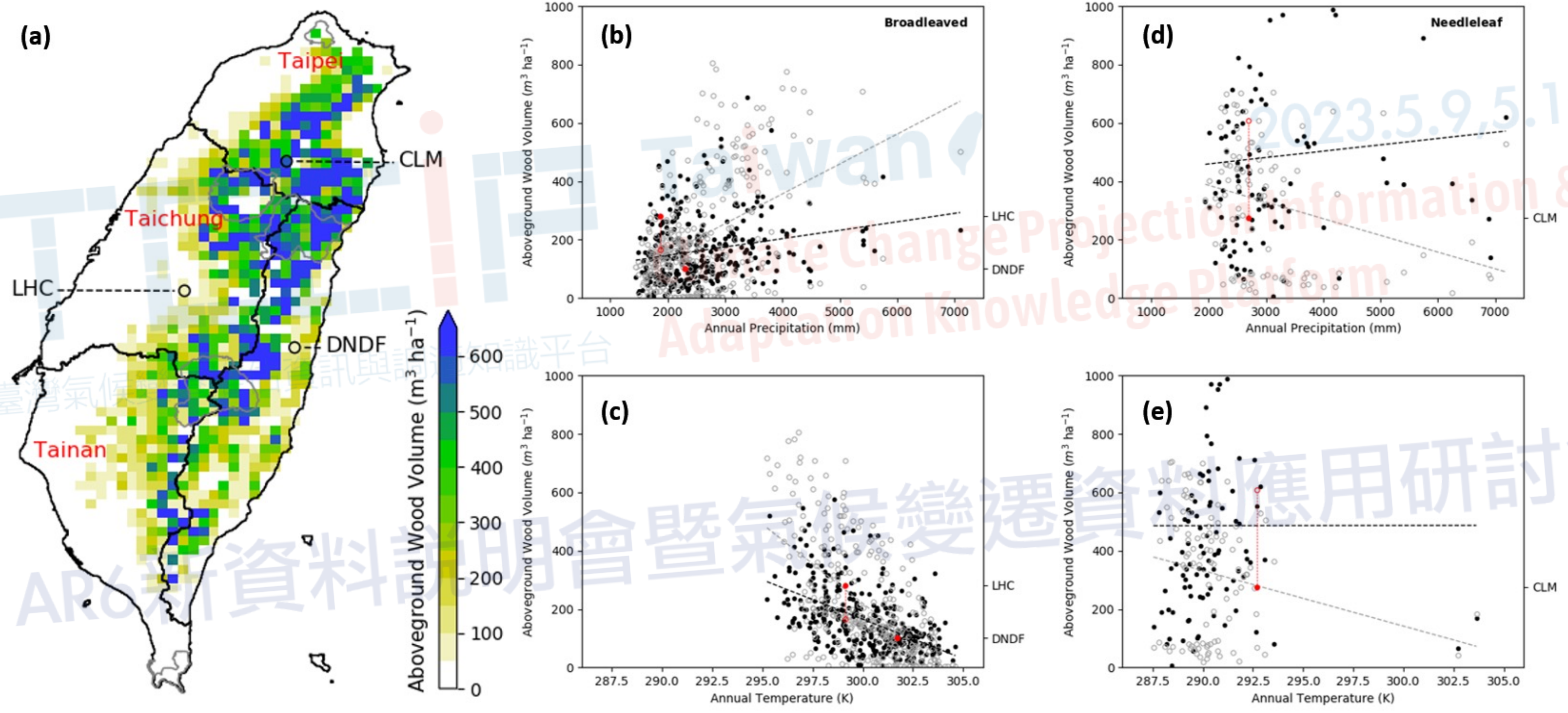
Lab Members:


(a)
Taipei
Taichung
Tainan
CLM
LHC
DNDF
Aboveground Wood Volume (m3 ha−1)
0
100
200
300
400
500
600
(b)
Broadleaved
(c)
(d)
Needleleaf
(e)
Aboveground Wood Volume (m3 ha−1)
Annual Precipitation (mm)
Annual Temperature (K)
1000
2000
3000
4000
5000
6000
7000
287.5
290.0
292.5
295.0
297.5
300.0
302.5
305.0
800