Winter leaf reddening phenomenon: Long-term track of PRI and phenological changes in a temperate Japanese cypress forest at Kiryu Japan

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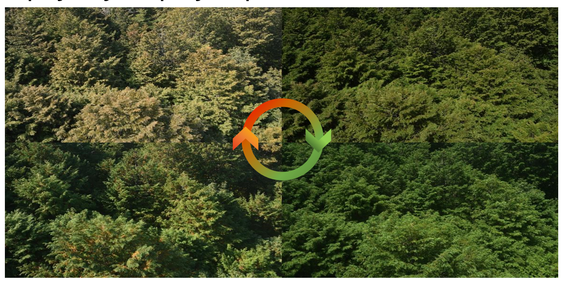
Introduction

Background

- Winter leaf reddening is the phenomenon that evergreen species' leaf changes color from green to red before or during winter due to the acclimation of red pigments
- Winter leaf reddening (last months) ≠ leaf reddening during senescence or development (last weeks)
- A classical explanation: the winter leaf reddening phenomenon is a **photoprotection** strategy, which may confer an advantage to evergreen species to achieve a positive carbon balance. In photoprotection process red pigment (Rhodoxanthin in gymnosperms) and xanthophyll cycle play important roles



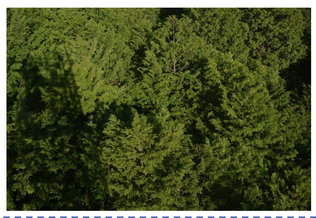
Purpose

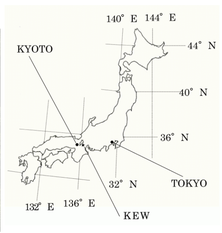
1. to verify the hypothesis: the joint role of Rhodoxanthin and the Xanthophyll Cycle in regulating Light-use efficiency may lead the winter leaf reddening phenomenon occurs
2. to find out when the winter leaf reddening occurs

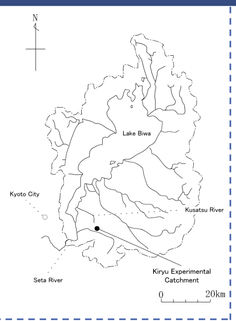
Method

Study site :Kiryu Experimental Watershed (code: KEW)

- Location: south Shiga, Japan(34° 58'N, 136° 00'E)
- Mean annual air temperature: 13.5℃
- Mean annual precipitation: 1630mm
- LAI: 4.5-5.5
- Canopy height: approximately 20m
- Vegetation: Japanese cypress







Tower Hight: 29m
Canopy Hight: 20m

Eddy covariance system

3D ultrasonic anemometer

SAT550*(Kaijo, Tokyo, japan)*

Gas analyzer

LI7500 *(LI-COR, USA)*

- **CO2 Flux & Light-use efficiency** (LUE)

Spectroradiometer

PGS-100*(PREDE Co.Japan)*

Spectral range (nm) 257-1093

- **Photochemical reflectance index** (PRI)

Meteorological data

Sensors in 1m,10m,20m,26m,29m

CR10,Campbell scientific

Photosynthetically active radiation *(PAR)*

LI190, LI-COR

Phenology monitor

Digital camera (3h intervals)

- **Phenological indices** (RGB chromatic coordinates & Red-Green Vegetation Index)

**(Kuwada al.,2017)*

Caculations

$$PRI = \frac{R_{531} - R_{570}}{R_{531} + R_{570}}$$

$$GPP = -(F_C + S_C) + RE$$

$$APAR = FAPAR * PAR$$

$$LUE = GPP/APAR$$

The data when the observed solar radiation amount was 35% or more of the solar radiation amount at the upper space atmosphere was regarded as clear day data. Higher than 60% is sunny day data.

Phenological analysis

The digital numbers were extracted from photos and then calculated RGB chromatic coordinates and RGVI as follow:

RGB chromatic coordinates

$$Rcc = R/(R+G+B)$$

$$Gcc = G/(R+G+B)$$

Red-Green vegetation index

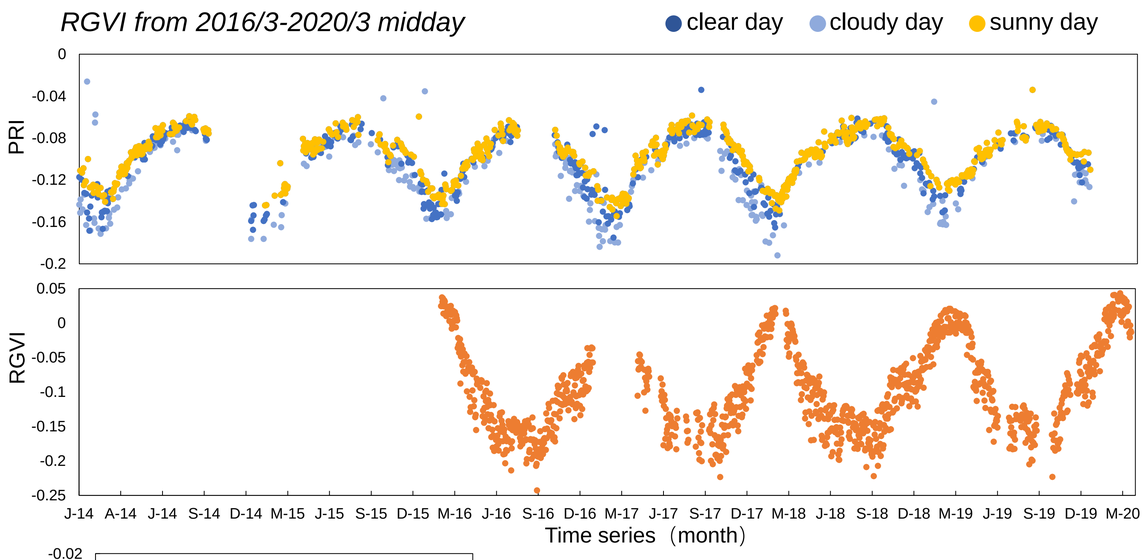
$$RGVI = (Rcc - Gcc)/(Gcc + Rcc)$$

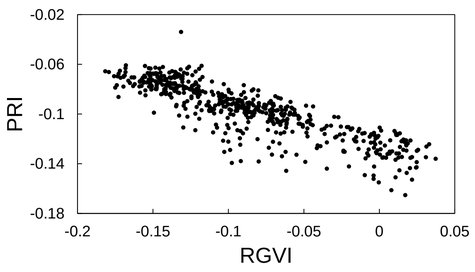
Results & Discussion

① The seasonal changes of PRI and RGVI

From 2014-2019 during 11:30-13:30 except rainy day.

RGVI from 2016/3-2020/3 midday





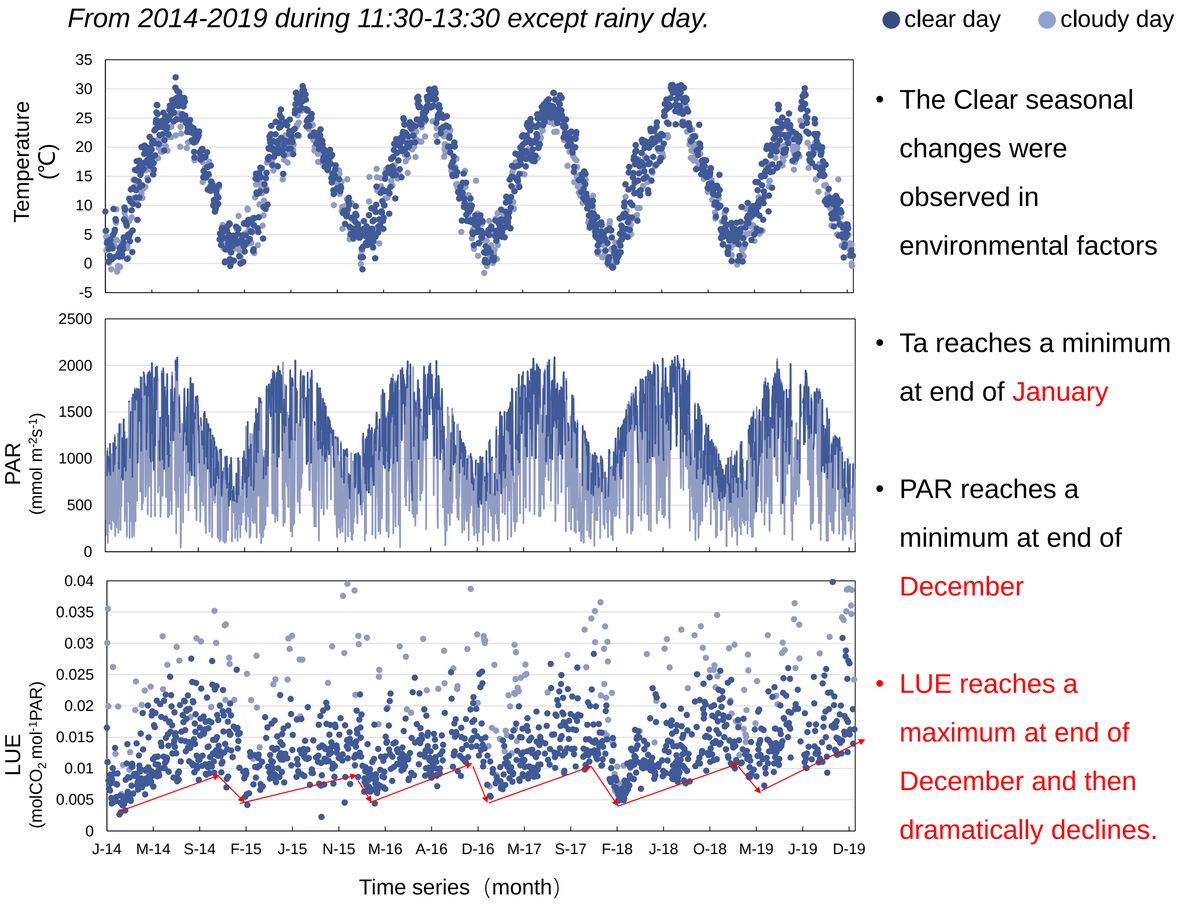
- The RGVI showed the seasonal changes with that of PRI almost in contrast
- Daily PRI is significantly correlated with RGVI (clear day)

**R= -0.8637, ***P < 0.001 in Pearson's correlation test*

- It suggested that the winter leaf reddening phenomenon occur along with the decline of PRI

② The inter-annual changes in air temperature, PAR, and LUE

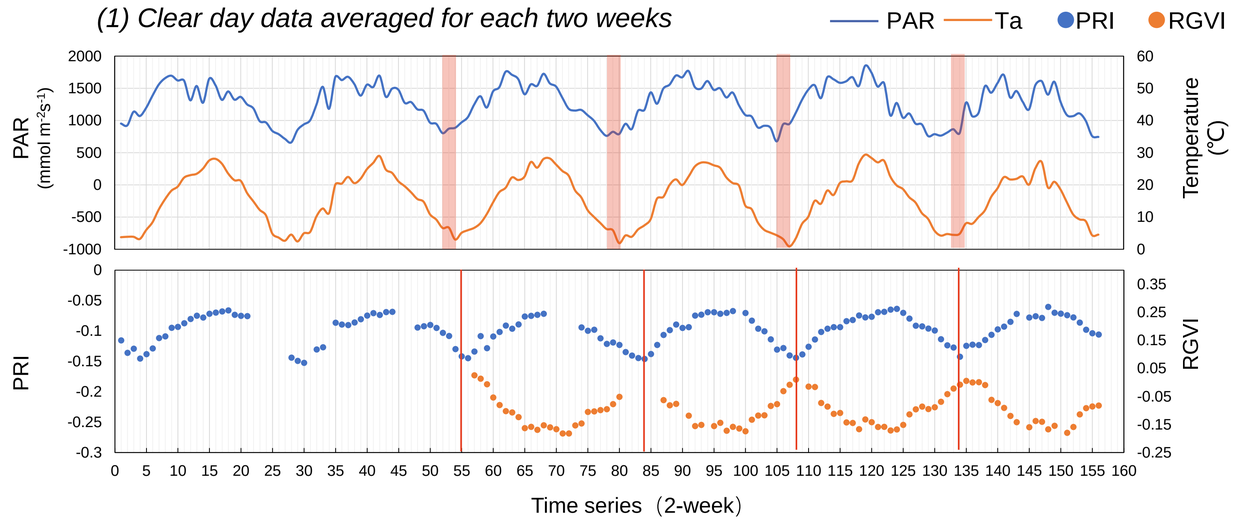
From 2014-2019 during 11:30-13:30 except rainy day.



- The Clear seasonal changes were observed in environmental factors
- Ta reaches a minimum at end of January
- PAR reaches a minimum at end of December
- LUE reaches a maximum at end of December and then dramatically declines.

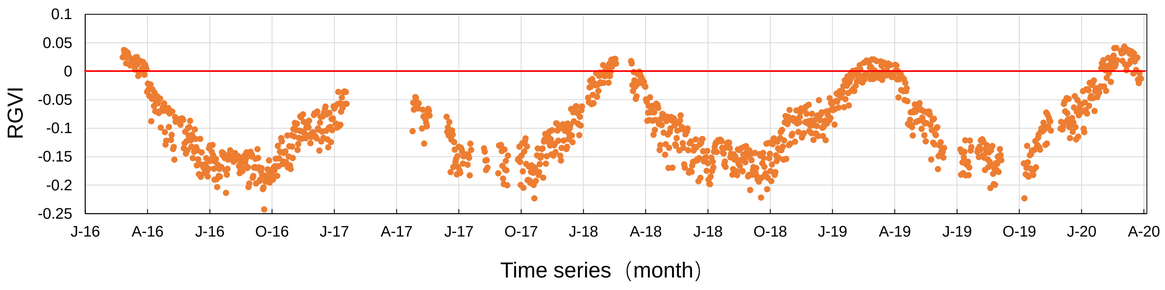
③ Winter leaf reddening occurring time and mechanism

(1) Clear day data averaged for each two weeks



The time lag between PAR and Ta reaching their minimum → Imbalance between light energy absorption and light energy utilization → LUE reaches a maximum at end of December and then dramatically declines, and the winter reddening mechanism is activated

(2) Daily RGVI from 2016/3- 2020/3 midday



$$RGVI = (Rcc - Gcc)/(Gcc + Rcc)$$

RGVI > 0, Rcc > Gcc
Red predominate.
RGVI < 0, Rcc < Gcc
Green predominate.

→ The approximate time when the winter leaf reddening occurs

- Starting time: early February (few days before or late than 2/4)
- Ending time: end of March (few days before or late than 3/31)
- Lasting time: nearly 2 months

Conclusions

The time lag between PAR and Ta reaching their minimum is approximately 4 weeks. The imbalance between light energy absorption and light energy utilization leads LUE to reach a maximum at end of December and then dramatically declines. To protect the photosynthetic apparatus from photodamage, the winter reddening mechanism is activated.

- In the photoprotection process, The rhodoxanthin and xanthophyll cycle played a collaborative role in regulating the LUE to adapt to a combination of the chilling temperature and high solar irradiances conditions. This mechanism leads to the occurrence of winter leaf reddening.
- The significant reddening on the leaf surface appear during the middle of February (2/11-2/18)
- The winter leaf reddening approximately starts around 2/4 and ends around 3/31. This phenomenon lasts for nearly 2 months.