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The responses of vegetation to climatic fluctuations using time-series MODIS data in a subtropical mountain cloud forest

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Extended abstract:

Disturbance may alter forest regeneration, composition, structure and function within a short period. Identifying vegetation growth and their responses to climatic fluctuations and large-scale disturbance such as typhoon and drought is necessary to understand the impacts of extreme weather on forest ecosystems (Wang and Chang 2021). In this study, we used 21 years (2001-2021) Moderate Resolution Imaging Spectroradiometer (MODIS) surface reflectance data with 8-day composite and calculated the Enhanced Vegetation Index (EVI), which is commonly utilized as a surrogate for leaf abundance (eq. 1):

$$EVI = \frac{G(\rho_{NIR} - \rho_{red})}{\rho_{NIR} + C_1\rho_{red} - C_2\rho_{blue} + L} \quad (1)$$

where ρ is the surface reflectance and the subscripts indicate near-infrared (NIR), red and blue bands. G is a gain factor; C1 and C2 are the coefficients of the aerosol resistance term; and L is the canopy background brightness correction factor. The coefficient in the MODIS EVI algorithm were G = 2.5, C1 = 6, C2 = 7.5 and L = 1 (Huete et al. 2002). To observe the long-term impacts of perturbations on vegetation, Taiwan ReAnalysis Downscaling data (TReAD) with 2 km spatial resolution from 1980 to 2021 from Taiwan climate change projection and adaptation information platform (TCCIP) (https://tccip.ncdr.nat.gov.tw/index_eng.aspx) were acquired to extract meteorological variables (temperature, wind speed and precipitation) (Lin and Lin 2021). We also calculated the standardized precipitation index (SPI) based on monthly precipitation with a three-month time scale (SPI-3), six-month time scale (SPI-6) and one-year time scale (SPI-12) to portray the precipitation variability during 2001-2021. The SPI is the transformation of monthly precipitation time series into a standardized normal distribution (z-distribution).

$$SPI = Z = \frac{MP_i - \overline{MP}}{MP_\sigma} \quad (2)$$

where MP_i, $\overline{MP}$ and MP_σ are month *i* precipitation, mean and standard deviation of monthly precipitation over the study period (Lana et al. 2001). The long-term climate data, including temperature, precipitation, wind speed and SPI were used to evaluate the responses of vegetation growth to climatic anomalies in a subtropical mountain cloud forest in northeastern Taiwan (Figure 1).

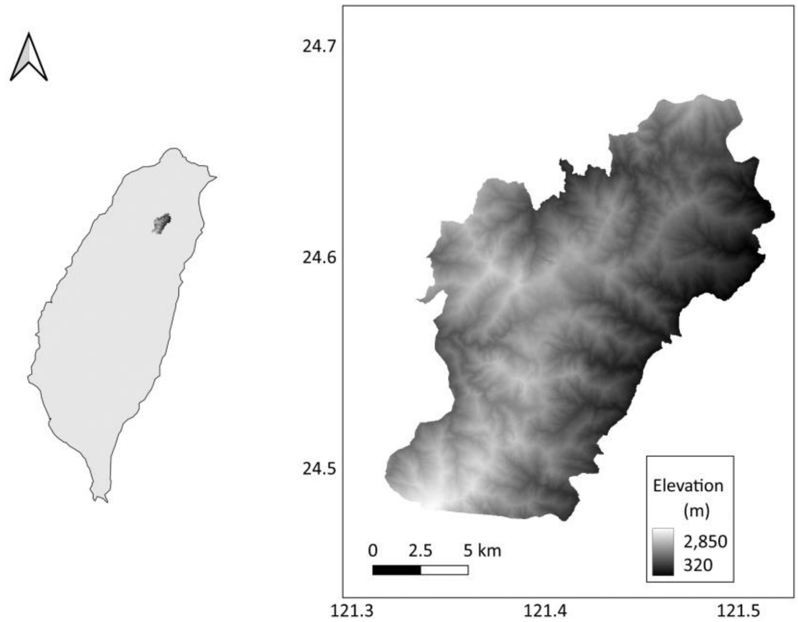

Figure 1. The study area in a subtropical mountain cloud forest in northeastern Taiwan.

The results showed that the monthly Enhanced Vegetation Index (EVI) had a significant positive relationship with concurrent monthly temperature (R^2 = 0.808, p < 0.001) (Figure 2a) and had a significant positively log-linear relationship with concurrent monthly precipitation (R^2 = 0.342, p < 0.001) (Figure 2b). Contrarily, the monthly EVI had a positively weak log-linear correlation (R^2 = 0.111, p < 0.001) with monthly maximum daily wind speed (Figure 2c), and had no significance with the Standard Precipitation Index of three months (SPI -3), SPI-6 and SPI-12 (p > 0.05) (Figure 2d). The annual EVI variability was significant difference based on one-way ANOVA test (p < 0.001) (Figure 3). The two highest annual average of EVI were the same value as 0.497 in 2013 and 2021, while the two lowest annual average of EVI were 0.441 and 0.448 in 2002 and 2003. The lowest annual EVI in 2002 and 2003 were related to severe drought event with the lowest SPI-3 -1.25 and -1.28, respectively (Figure 4). The monthly EVI change (%) in tropical cyclone perturbed period indicated that the severe wind speed from tropical cyclone could make the reduction of EVI, but the decrease of EVI was affected not only by intensity of cyclone but also by other factors (Figure 5).

Overall, although the impacts of severe typhoon caused the obvious decreases of monthly EVI in 2005 and 2015, the annual mean EVI had subtle change. The responses of vegetation to climatic fluctuations showed that the severe drought anomaly could be more dominant on this subtropical mountain cloud forest than typhoons.

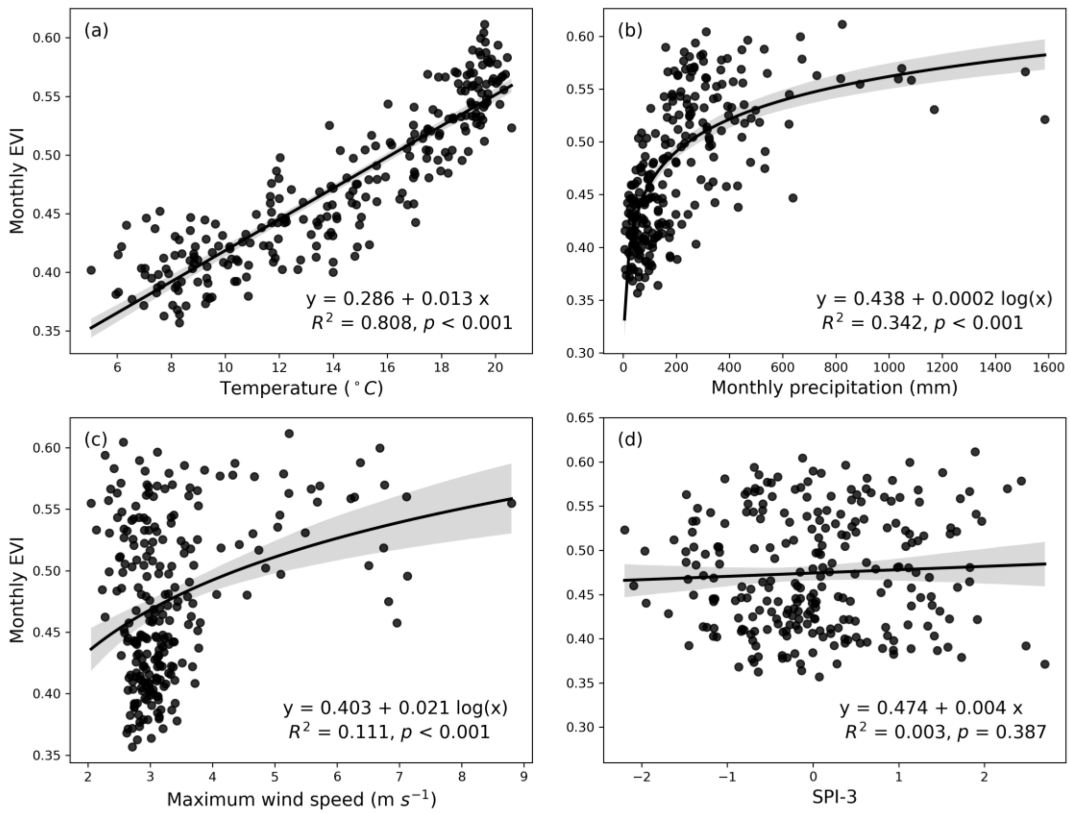

Figure 2. (a) The relationship between monthly EVI and mean of temperature. (b) The relationship between monthly EVI and monthly precipitation. (c) The relationship between monthly EVI and maximum daily wind speed. (d) The relationship between monthly EVI and mean of SPI-3.

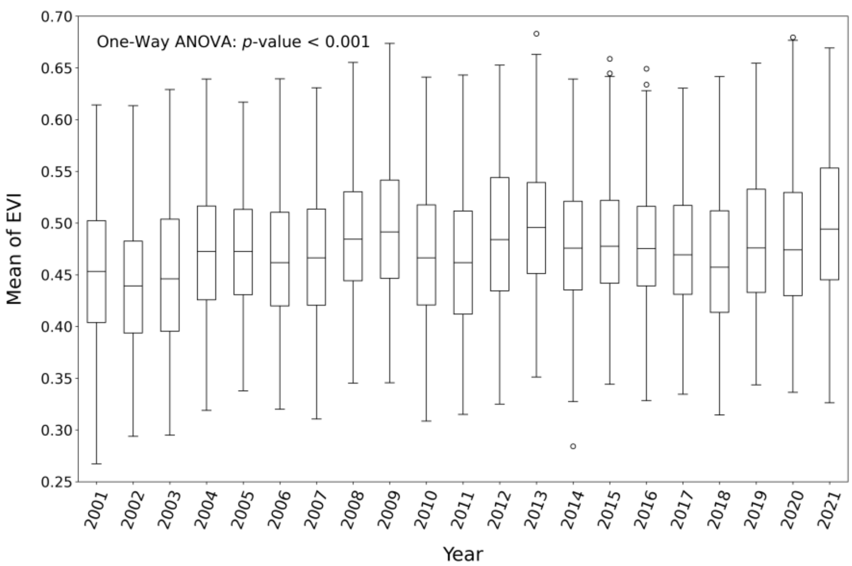

Figure 3. The annual average of EVI during 2001-2021. The annual average of EVI was significant difference based on one-way ANOVA test (p < 0.001).

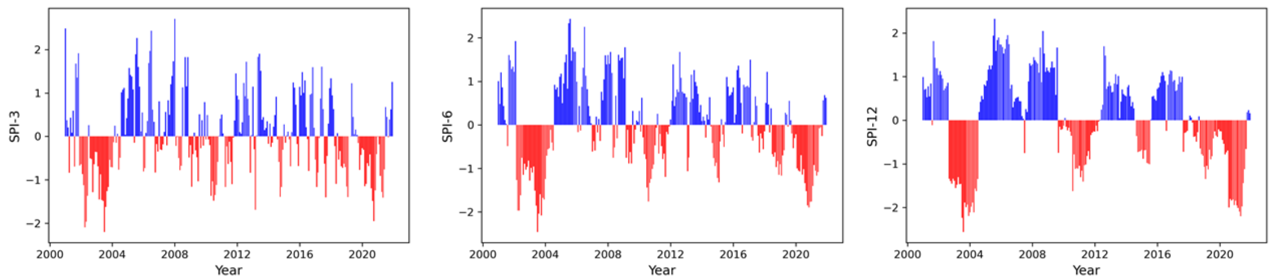

Figure 4. The patterns of a three-month time scale (SPI-3), six-month time scale (SPI-6) and one-year time scale (SPI-12) during 2001-2021.

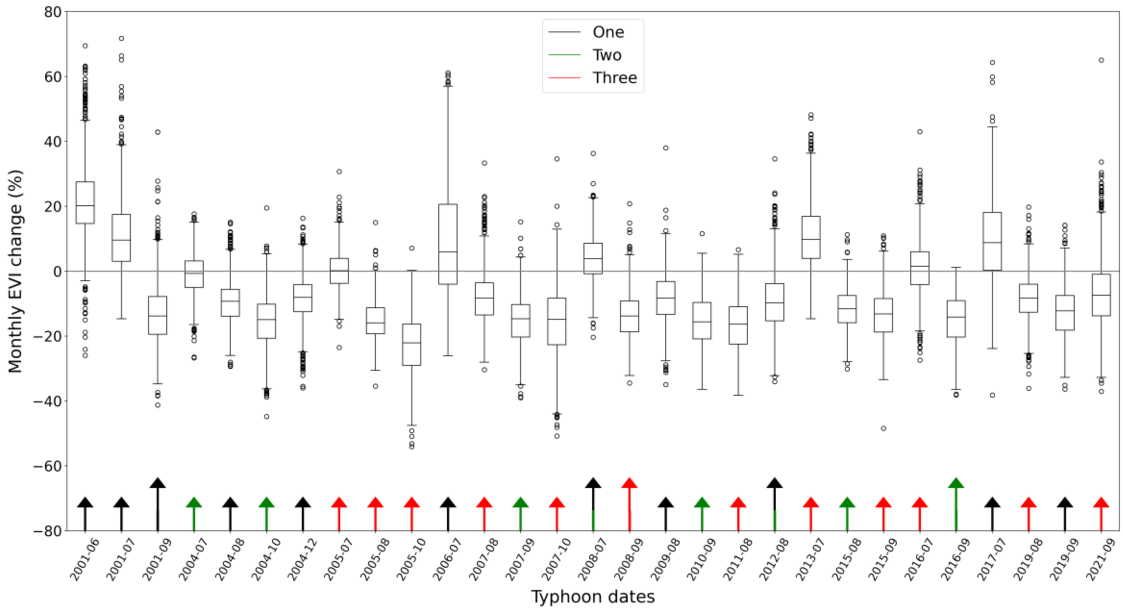

Figure 5. The monthly EVI change (%) per episodic event of tropical cyclone. The tropical cyclone was classified into category one, two and three by Saffir–Simpson hurricane wind scale.

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