Climate and Environment Drivers of Mangrove Phenology in Thailand

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Outlines

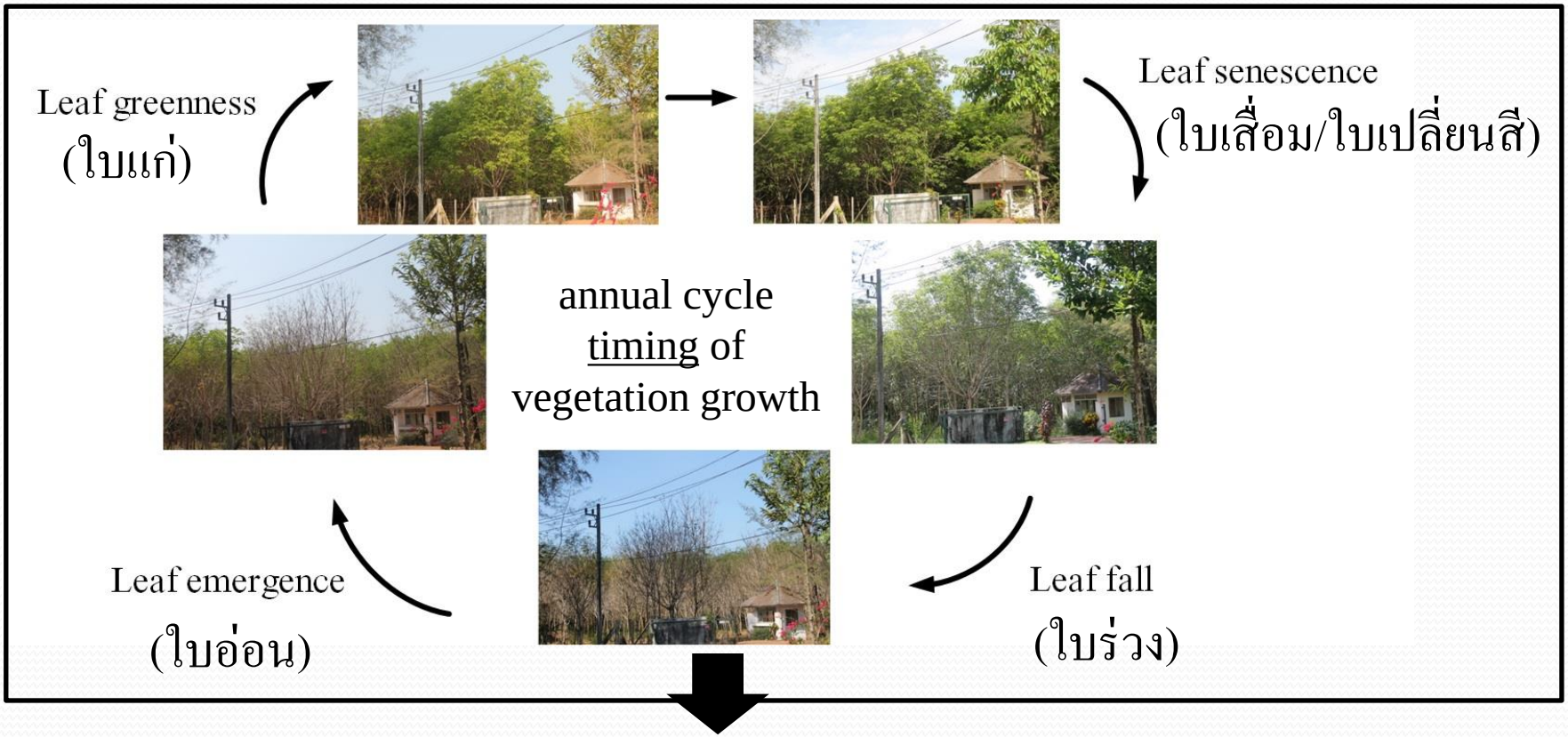
(1) Introduction
(2) Objectives
(3) Study area
(4) Methodology
(5) Results and discussions
(6) Conclusions

(1) Introduction

1.1 What is vegetation phenology?
1.2 What is importance of mangrove phenology?
1.3 How does phenology study?

1.1 What is vegetation phenology?

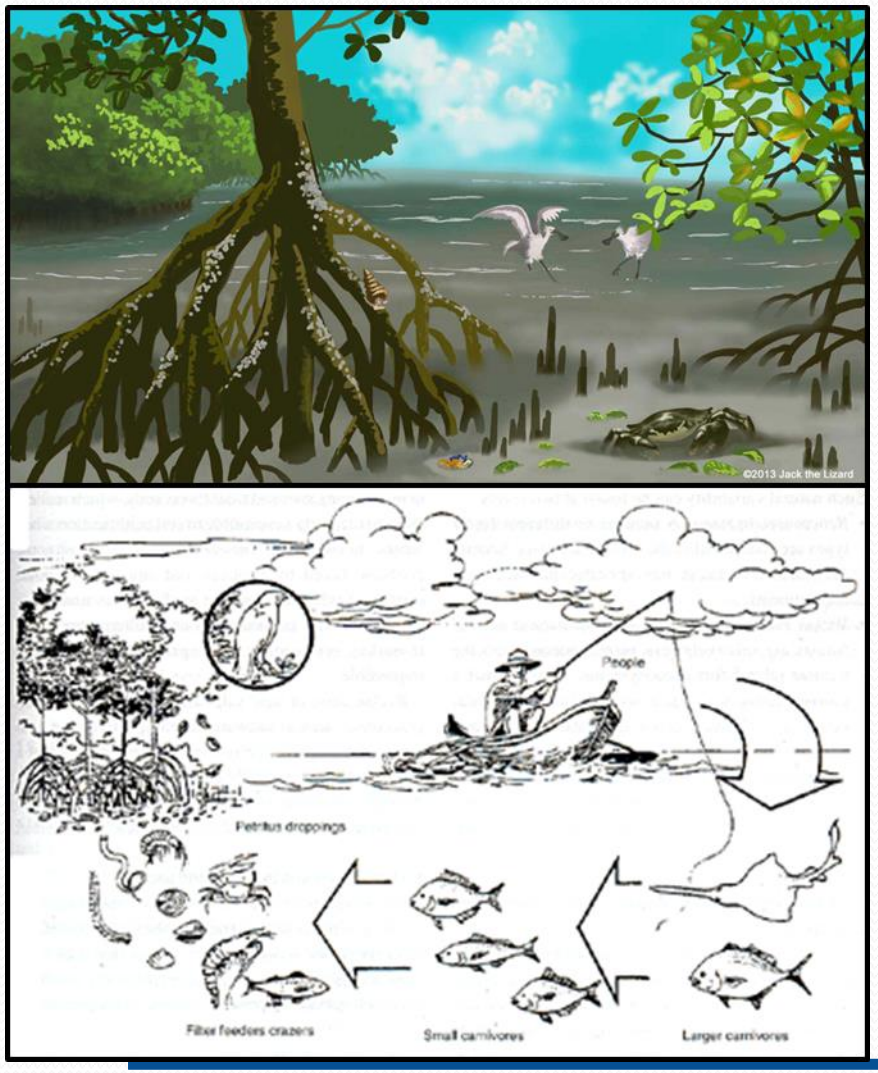
Vegetation phenology is the annual cycle timing of vegetation growth



The climate and environmental factors are control the vegetation growth.

Note: The figure shows phenology of Rubber tree.

1.2 What is importance of mangrove phenology?



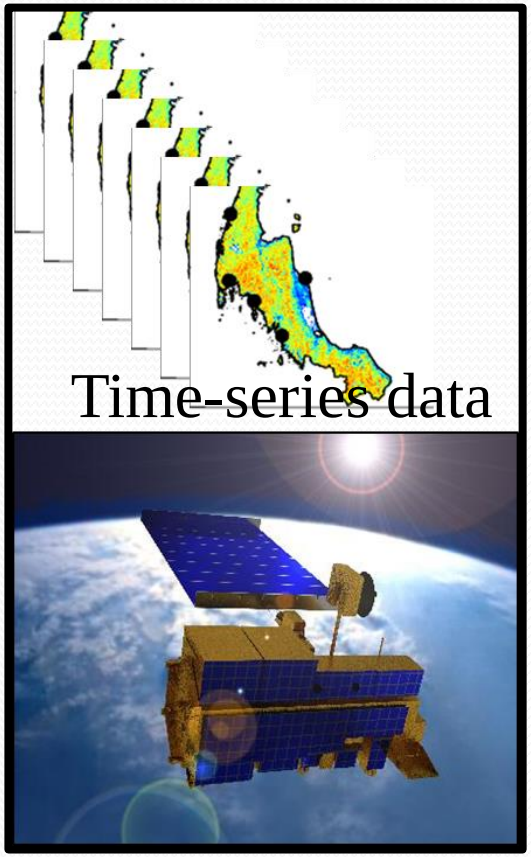
1) **Ecosystem valuable such as** long-term storage of abundant biomass and organic carbon, reducing shoreline erosion etc.
2) **Economic valuable** such as biological filters in polluted coastal areas, supporting estuarine food chains and providing habitats for invertebrates and juvenile fish fishery products, timber product.

1.2 What is importance of mangrove phenology?

- Changes in mangrove phenology from climate and environment drivers may affect broad-scale ecosystem activity in mangrove forests.
- Understanding of the environmental drivers is a key element for sustainable conservation of mangrove forests such as replanting management.

1.3 How does phenology study?

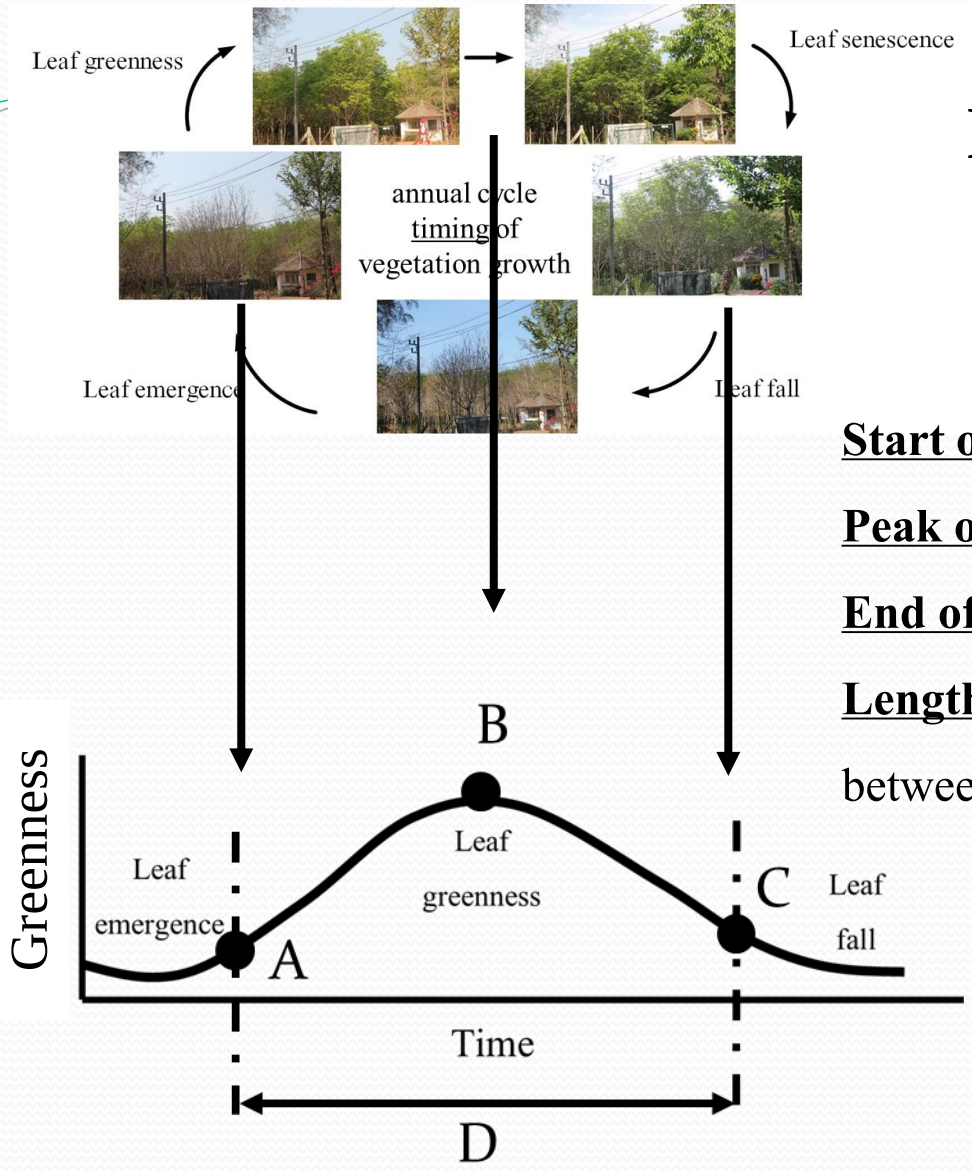
Satellite imageries



&

Digital repeat photography (Phenocam)

Phenology in remote sensing term



Phenology parameters

Start of season (A) is time of refer to leaf emergence.

Peak of season (B) is time of refer to leaf greenness.

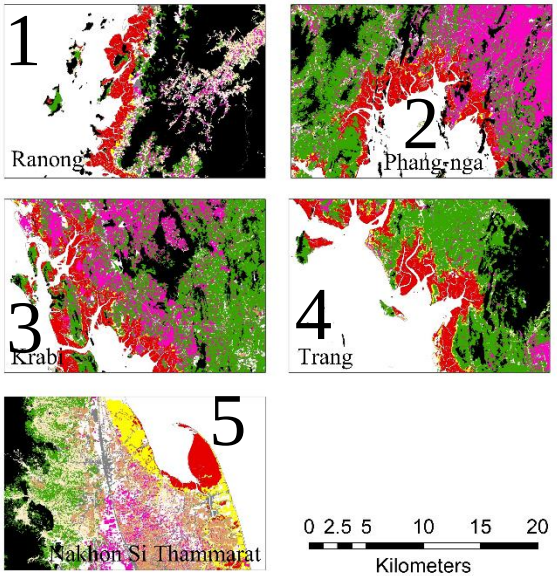
End of season (C) is time of refer to leaf senescence.

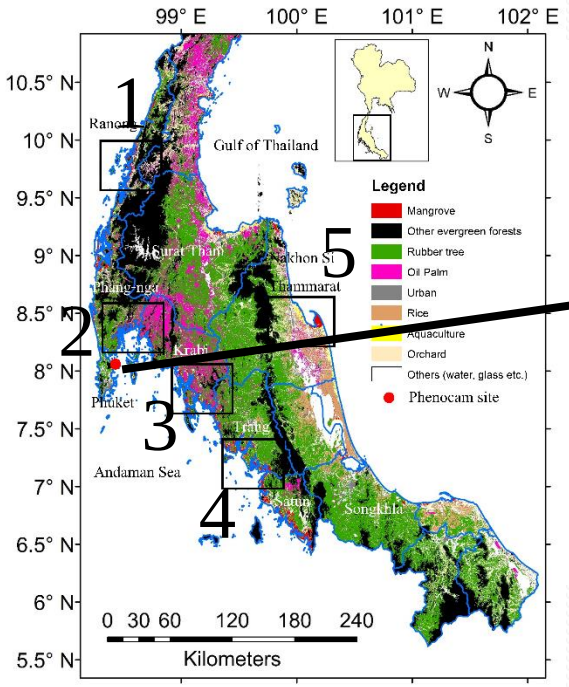
Length of season (D) is difference of the timing between start and end of season.

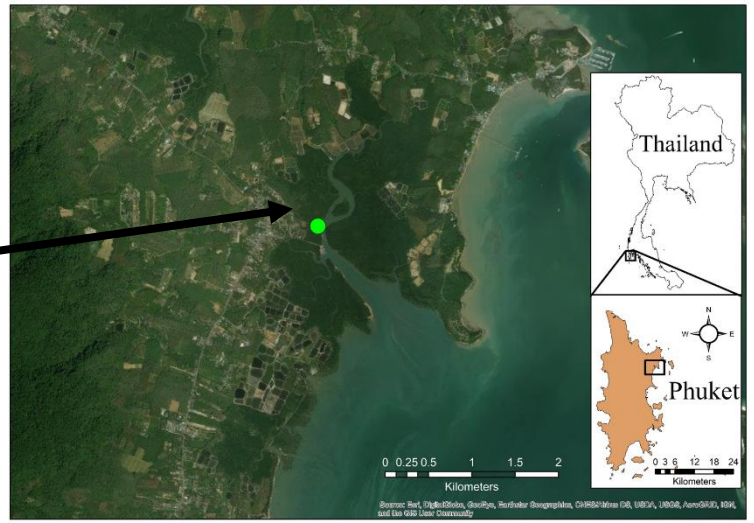
(2) Objectives

1) To characterize the variability in phenology patterns across equatorial Thailand Indo-Malay mangrove forests;
2) To identify the climate and aquatic drivers of mangrove seasonality;
3) To compare mangrove phenologies with surrounding upland tropical forests.

(3) Study area







Phenocam site

- Each mangrove sites are protected by the Thai government.
- NO. 1 – 4 are at the Andaman Sea area.
- NO. 5 is at the Gulf of Thailand area.
- The dominant species is *Rhizophora apiculate*.

(4) Methodology

4.1 Vegetation index

4.2 Mangrove's driver data

4.3 Analysis

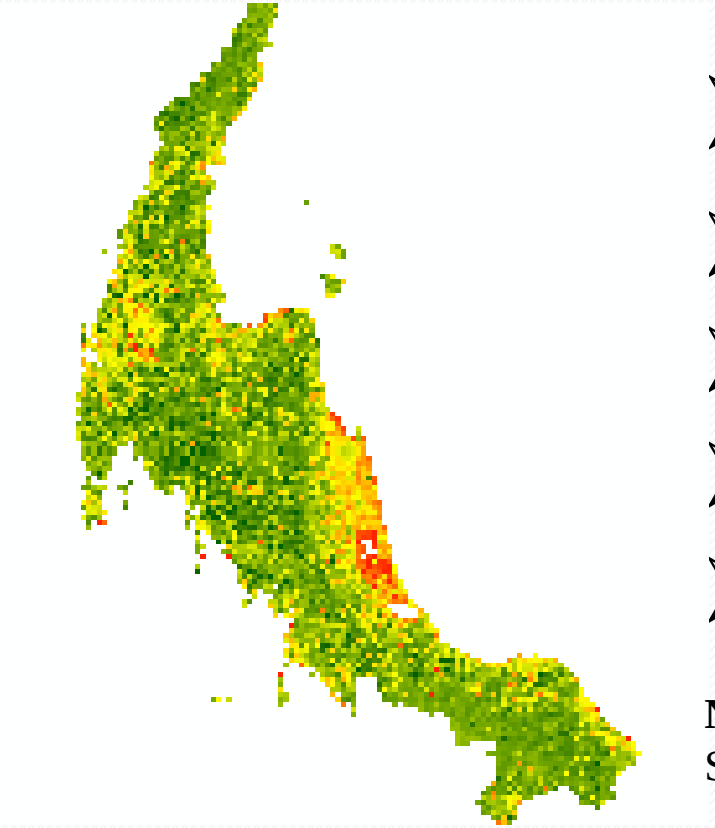
4.1 Vegetation index

$$EVI = 2.5\frac{\rho_{NIR} - \rho_{\mathrm{Re}d}}{\rho_{NIR} + 6\rho_{\mathrm{Re}d} - 7.5\rho_{Blue} + 1}$$

Advantage of EVI (Enhance vegetation index):

1) reduce noise from cloud or atmosphere in tropical zone.
2) improve atmospheric effects and soil background.

4.1 Vegetation index



- MODIS, MOD13Q1
- Year: 2002 – 2014
- 250 m x 250 m
- 16 days, 23 images/year
- Data source: USGS

NOTE: The MOD13Q1 data were re-projected from Sinusoidal projection to Geographic projection, WGS 1984.

The data were converted from 16 day EVI to monthly EVI

4.2 Mangrove drivers data

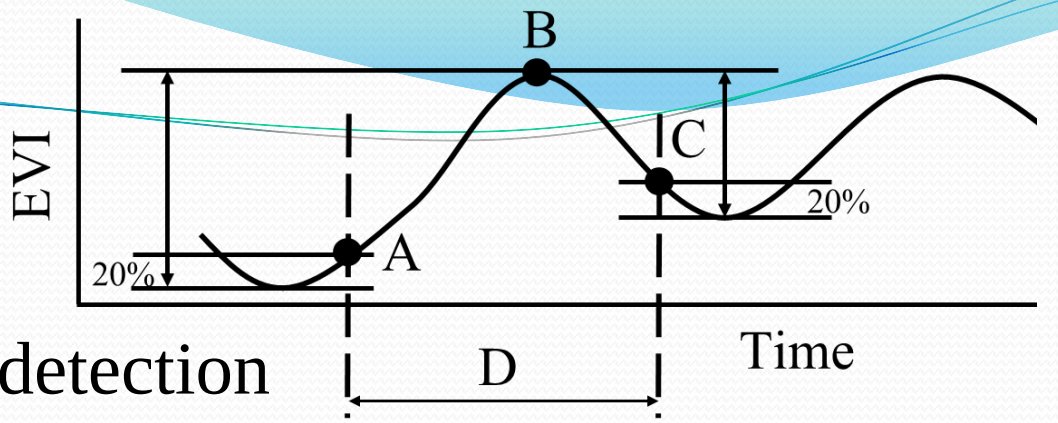
Drivers	Name	Spatial resolution	Data sources
Climate	Rainfall (TRMM-3B43)	0.25° x 0.25°	NASA
	Temperature (Air and land surface)	0.25° x 0.25°	NASA
	Radiation	0.25° x 0.25°	NASA
Aquatic	Sea surface temperature	4 km x 4 km	NASA
	Sea surface salinity	0.5° x 0.5°	Argo

- Due to the limitation service of some data source, the monthly data from 2003 to 2012 are used for calculation relationship between EVI and drivers.
- Due to there were several spatial resolutions, the pixel of both EVI and drivers data that covered each of the mangrove areas were extracted and averaged into monthly data.

https://hydro1.gesdisc.eosdis.nasa.gov/data/GLDAS/

http://mirador.gsfc.nasa.gov http://www.argo.ucsd.edu

4.5 Analysis



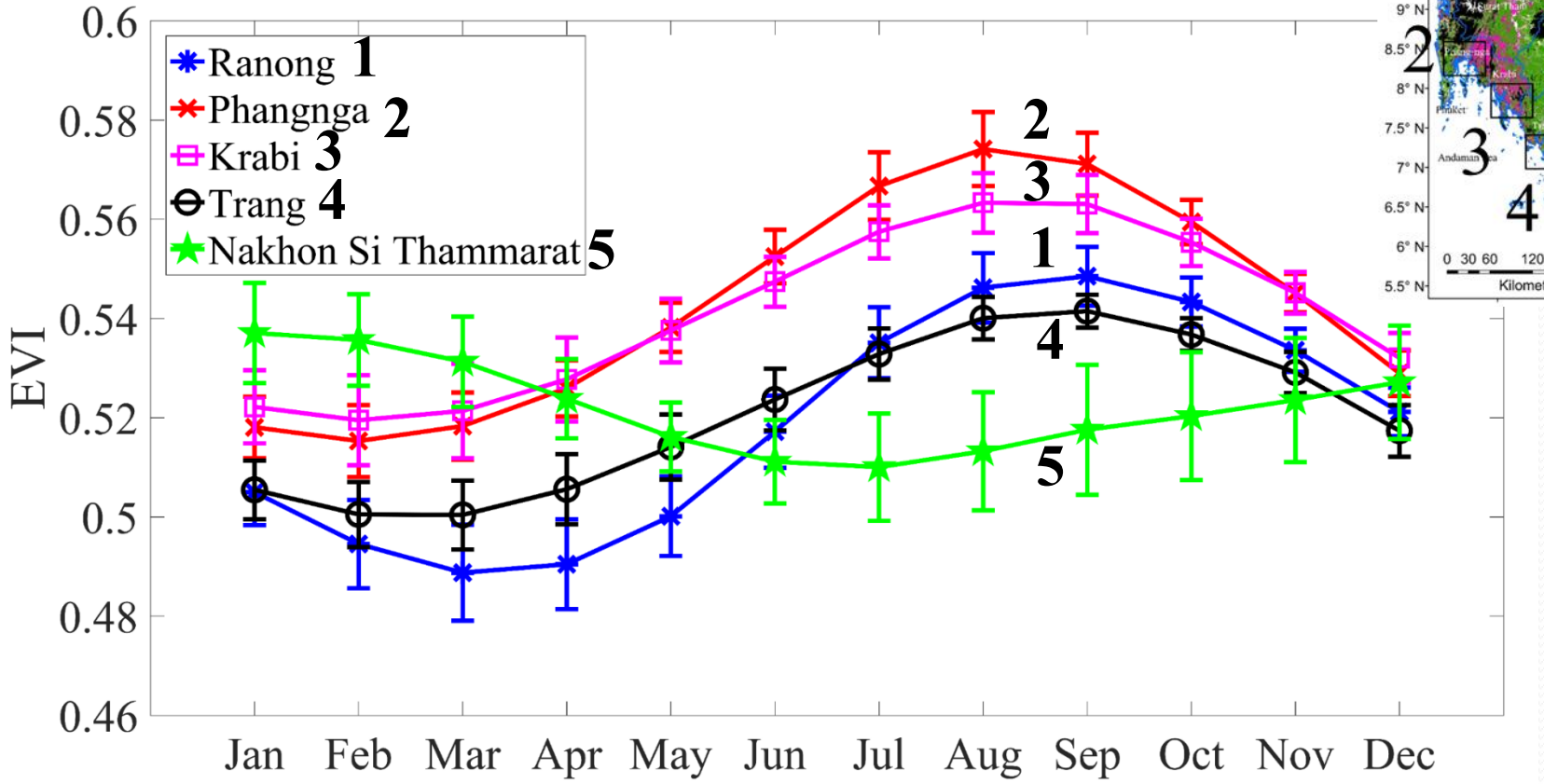
(1) Based on satellite detection

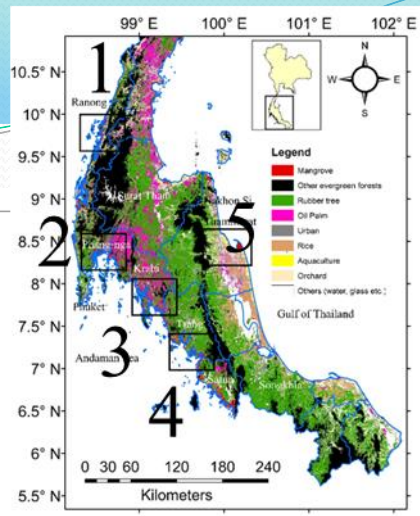
- **TIMESAT** software is used to extract phenology parameters [start of season (point A), peak of season (point B), end of season (point C), length of season (point D)].
- **Savitsky-Golay** smoothing filter was applied to remove noise in MODIS-EVI time series before calculating phenology parameters.
- **Boxplot** was applied for comparison phenology of the study site and surrounding forest.
- Correlation coefficient **(r)** was selected to calculate the relationship between **monthly EVI and climate/aquatic drivers**. **Lag analysis** was also applied. (not effected immediately)

(5) Results and discussions

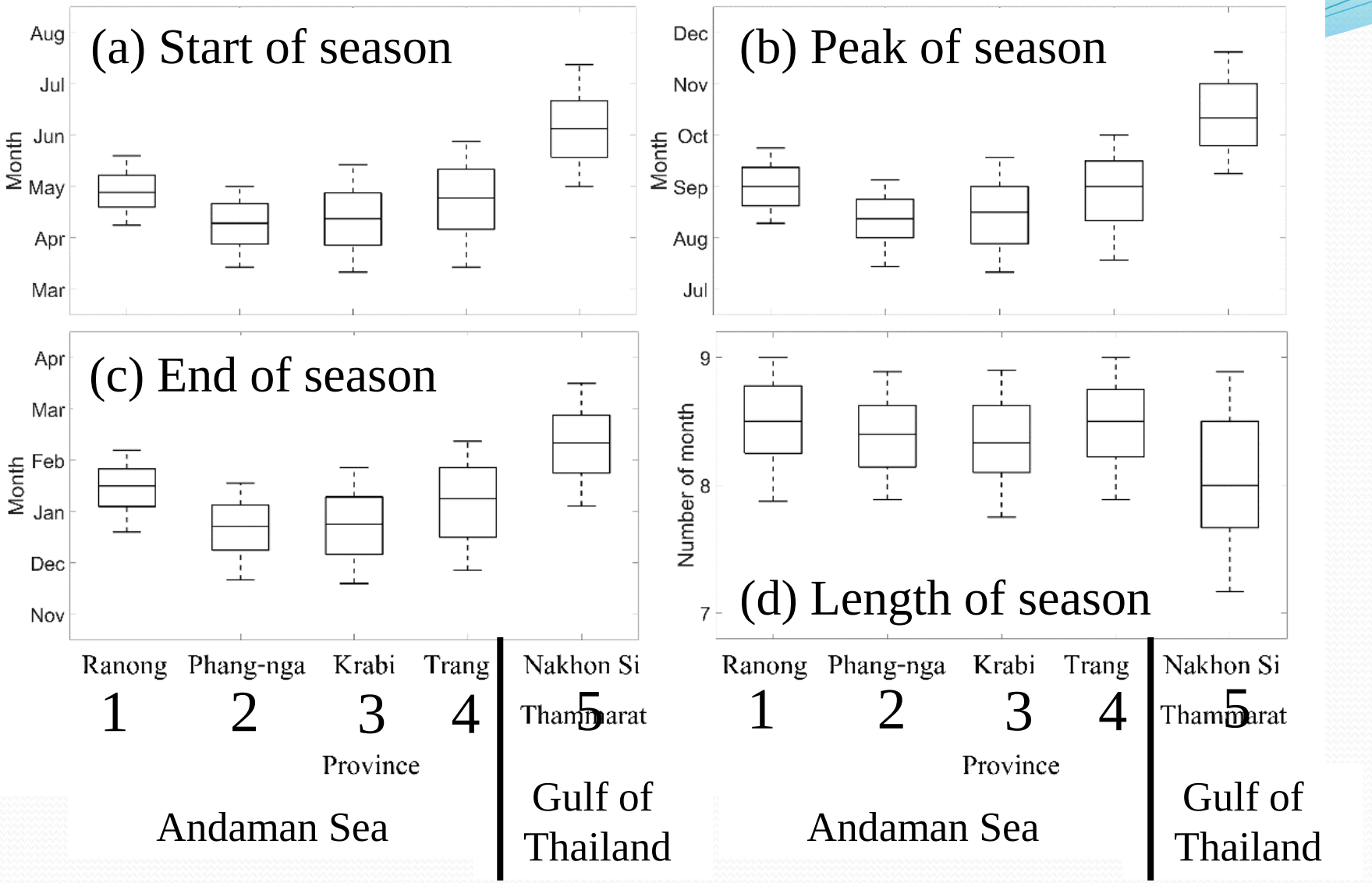
From the objective:

1) To characterize the variability in phenology patterns across equatorial Thailand Indo-Malay mangrove forests;





Mangrove seasonal profiles from EVI-MODIS over five local sites of Southern Thailand averaged across 13 years.

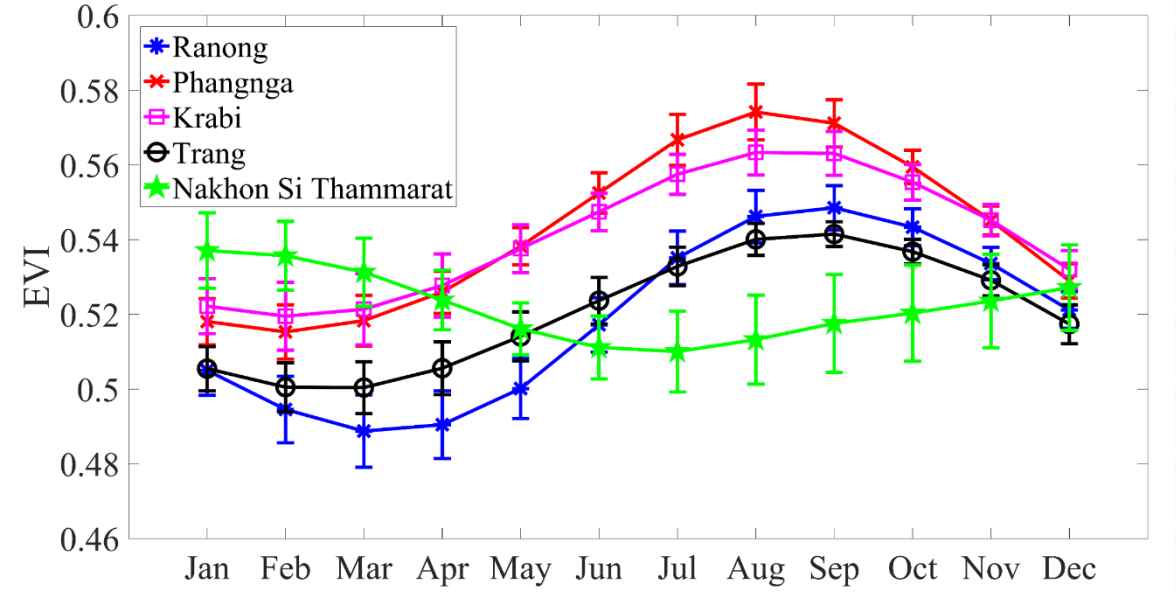


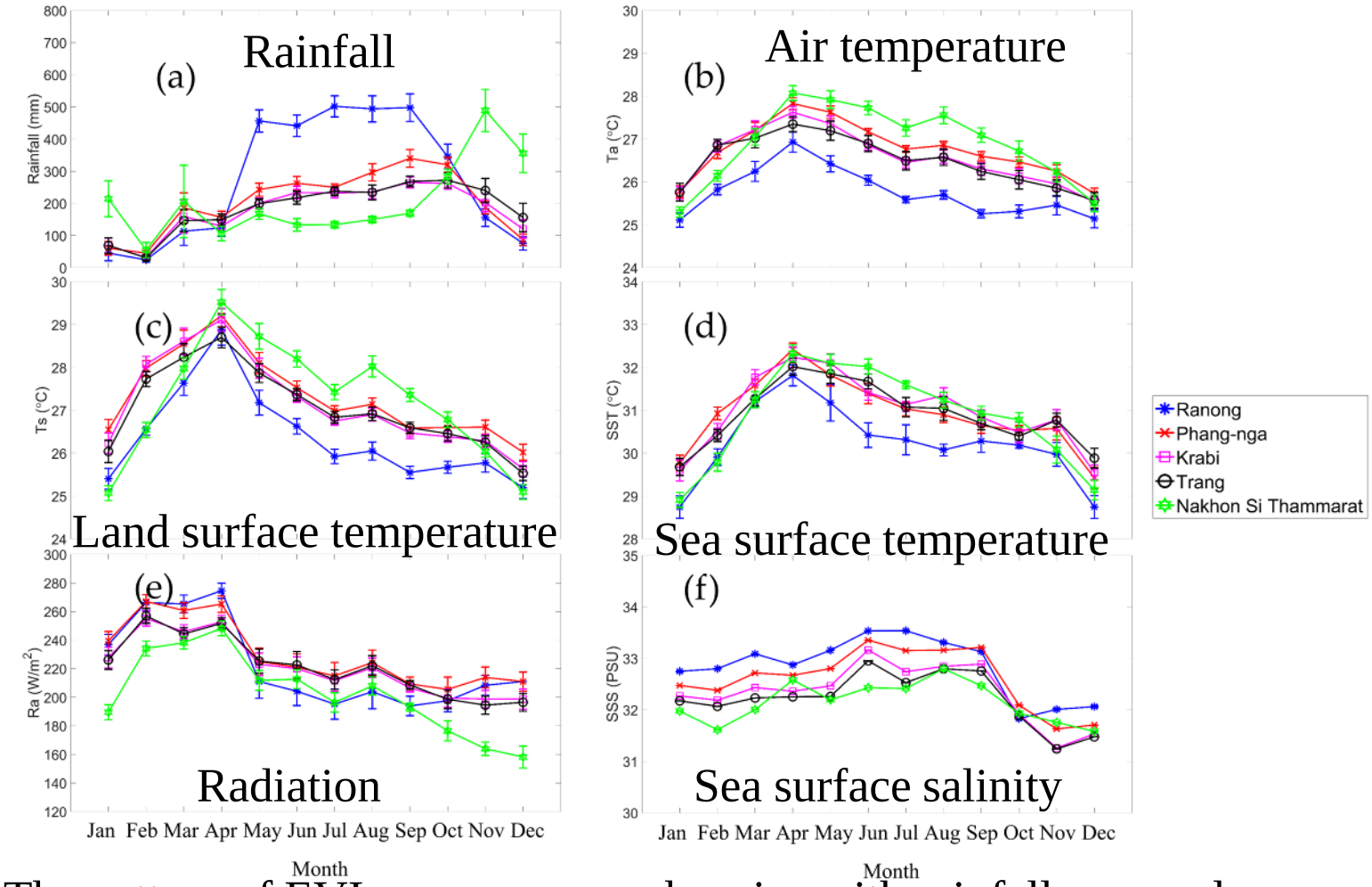
- The appearance of new leaves periods of *Rhizophora apiculata* at Phuket is corresponding to the report of CHRISTENSEN and WIUM-ANDERSEN (1977).

(5) Results and discussions

From the objective:

2) to identify the **climate (rainfall, air temperature, land surface temperature, and radiation)** and **aquatic (sea surface temperature and salinity)** drivers of mangrove seasonality;





- The pattern of EVI mangrove synchronize with rainfall seasonal
- The start of season, peak of season, and end of season occurred before pre-monsoon, during the monsoon and post-monsoon, respectively corresponded to tropical mangroves in India (Rani et al, 2016).

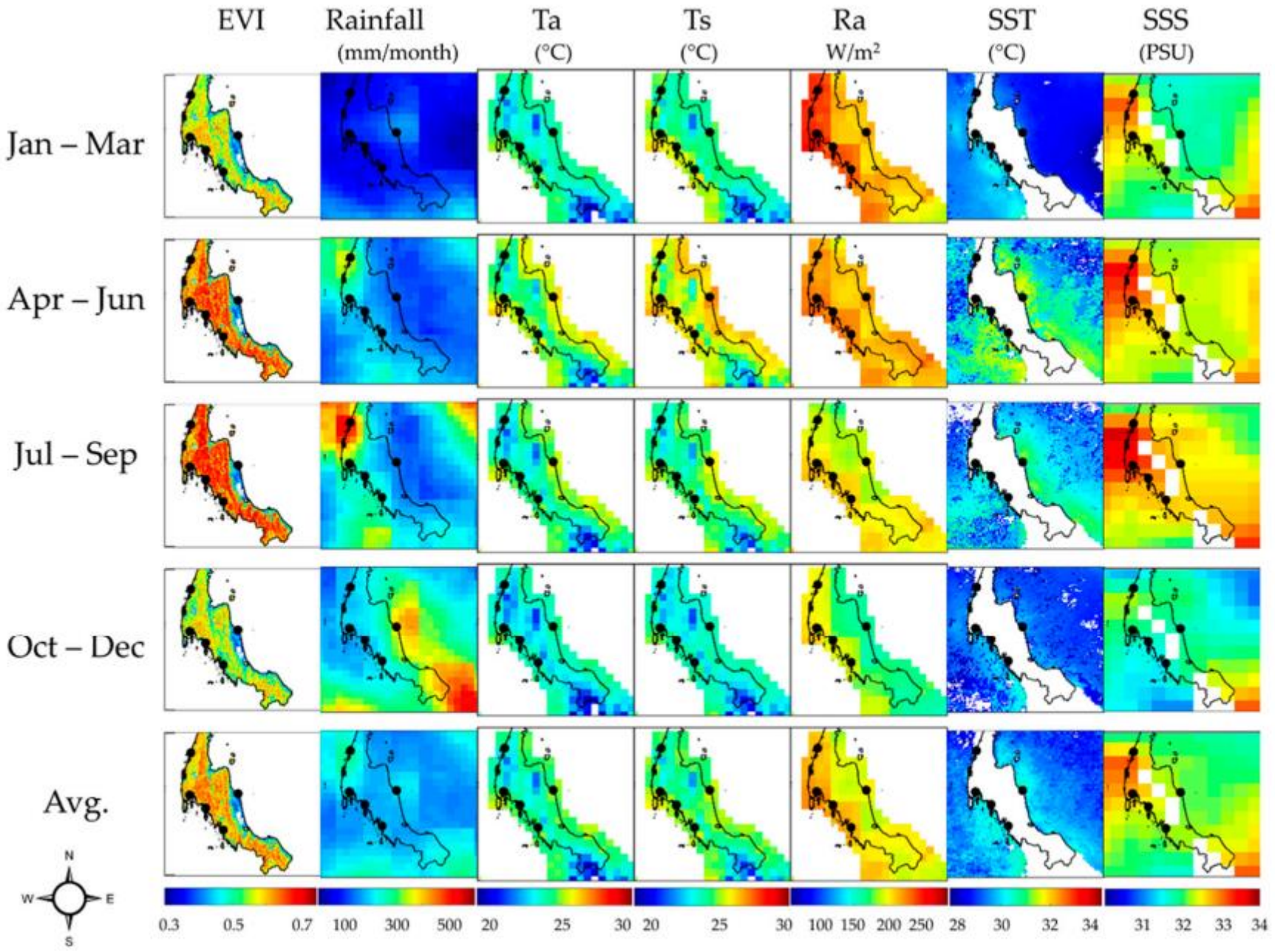
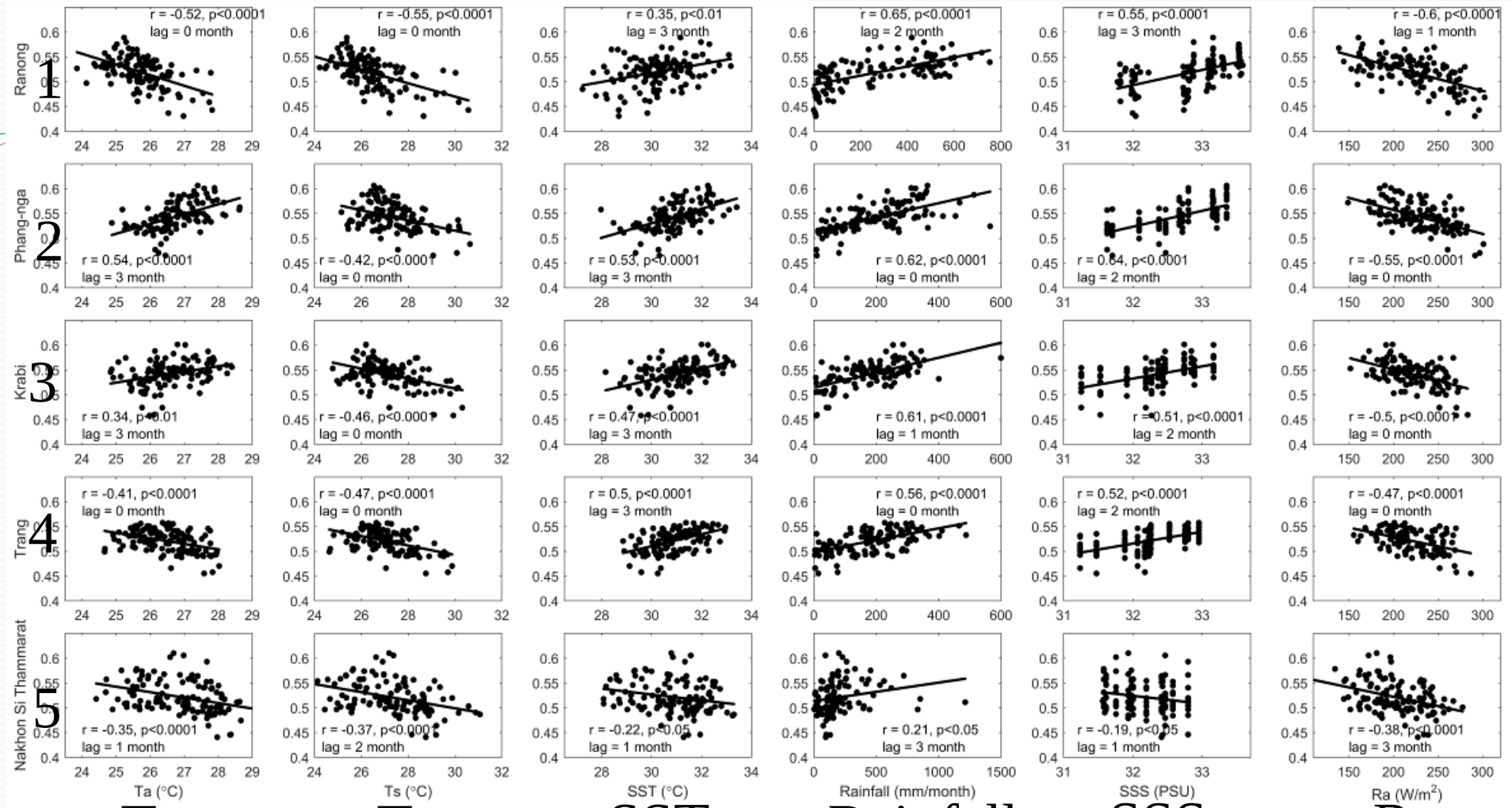
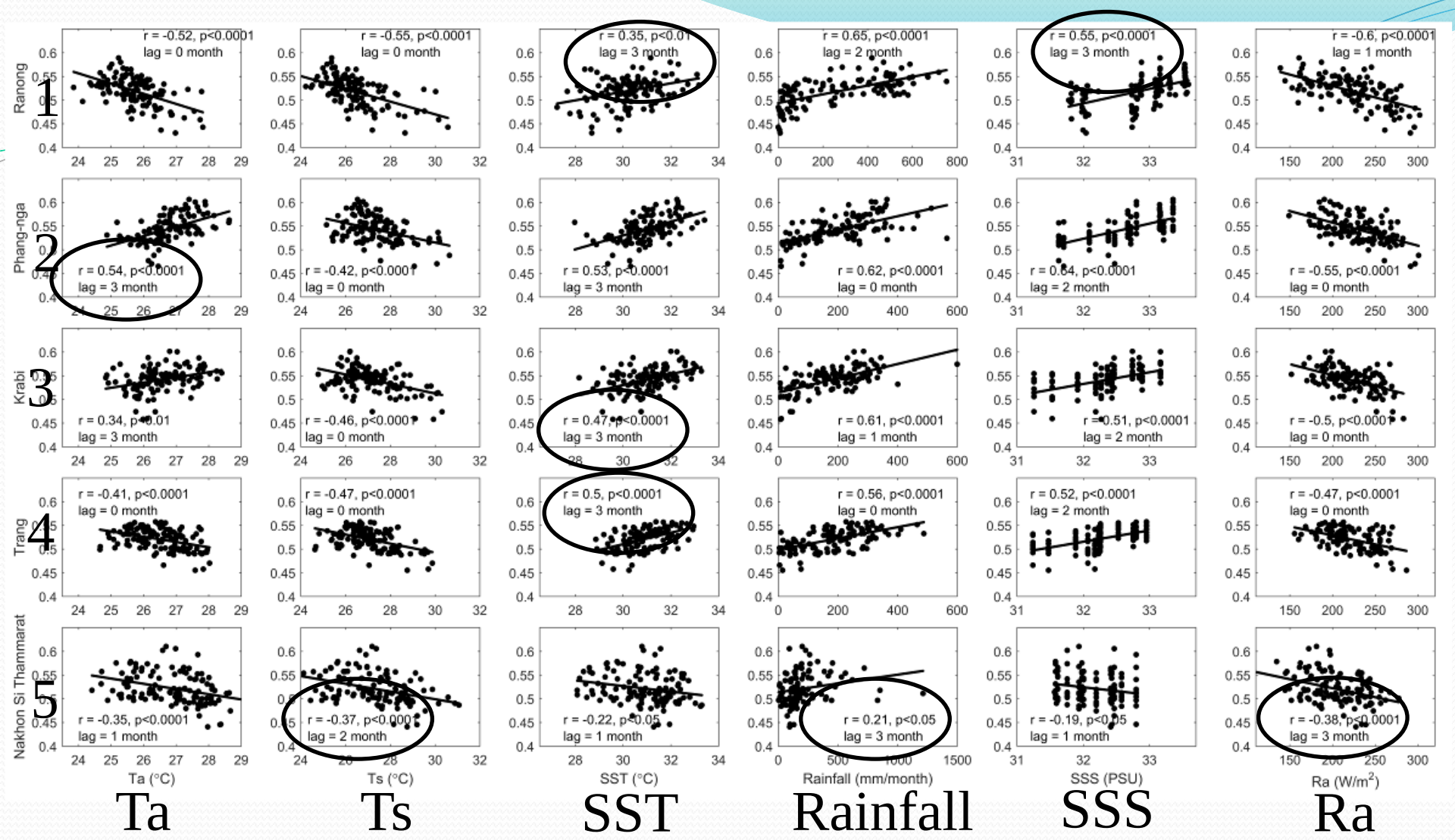


Figure 9. Color-coded spatial variability of seasonal EVI and seasonal environmental/climate driver values at quarterly intervals. The points are the location of the study sites.



Scatterplot of monthly relations between EVI and drivers, including air temperature (Ta), land surface temperature (Ts), sea surface temperature (SST), rainfall, sea surface salinity (SSS) and radiation (Ra) at the five study sites.



Scatterplot of monthly relations between EVI and drivers, including air temperature (Ta), land surface temperature (Ts), sea surface temperature (SST), rainfall, sea surface salinity (SSS) and radiation (Ra) at the five study sites.

By summary,

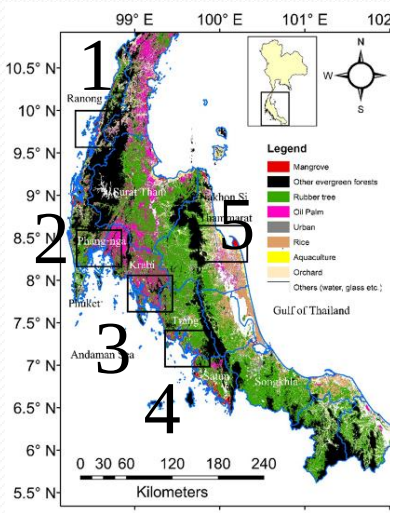
- EVI of mangrove was positively correlated with the rainfall seasonal at both side of Southern Thailand that agreed with the findings of Suepa et al. (2016) who reported that the tropical forest was regulated by rainfall magnitude and seasonality.
- According to report of Clinton et al. (2014) and Prasad et al. (2007), there was no significant correlation of EVI with SST due to lags in vegetation responses. In this study, confirmed that the EVI mangrove response lagged SST of about 1 to 3 months.

(5) Results and discussions

From the objective:

3) To compare mangrove phenology with surrounding upland tropical forests (**oil palm, and rubber tree plantations and other evergreen tropical forests**);

Color-coded averaged of phenology over the period 2003 to 2012



Site name

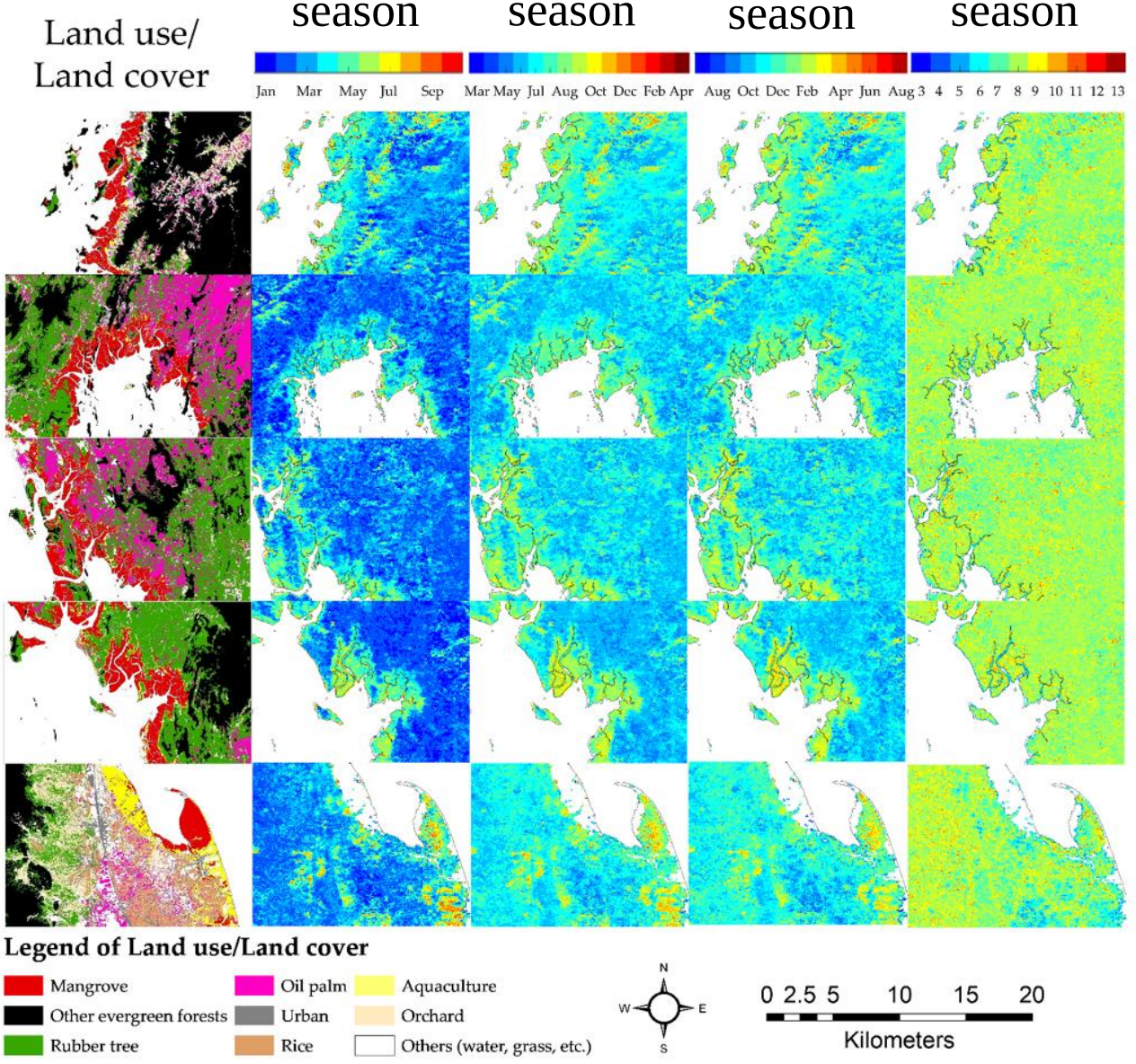
1 Ranong

2 Phang-nga

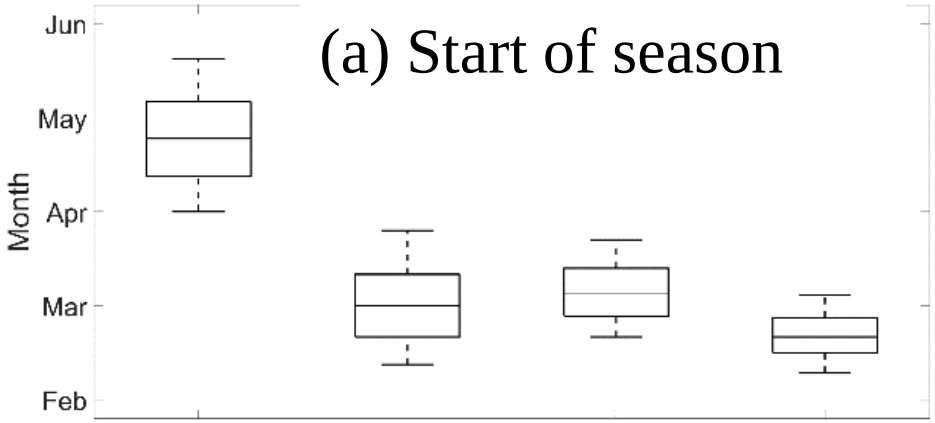
3 Krabi

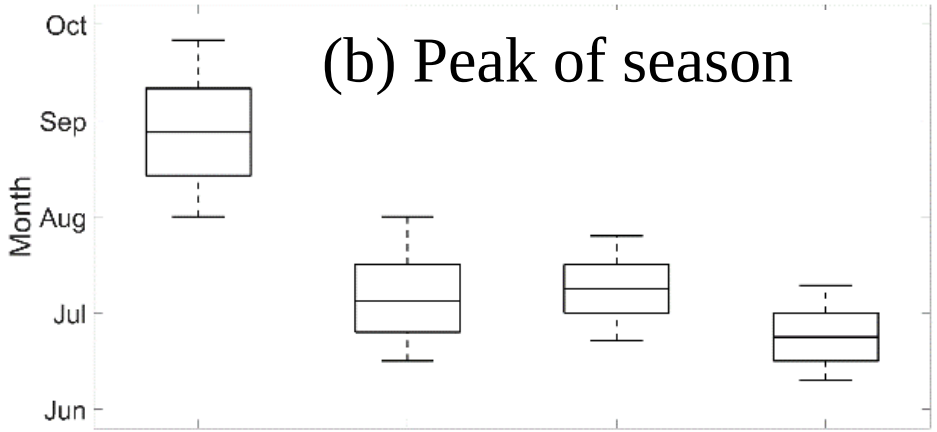
4 Trang

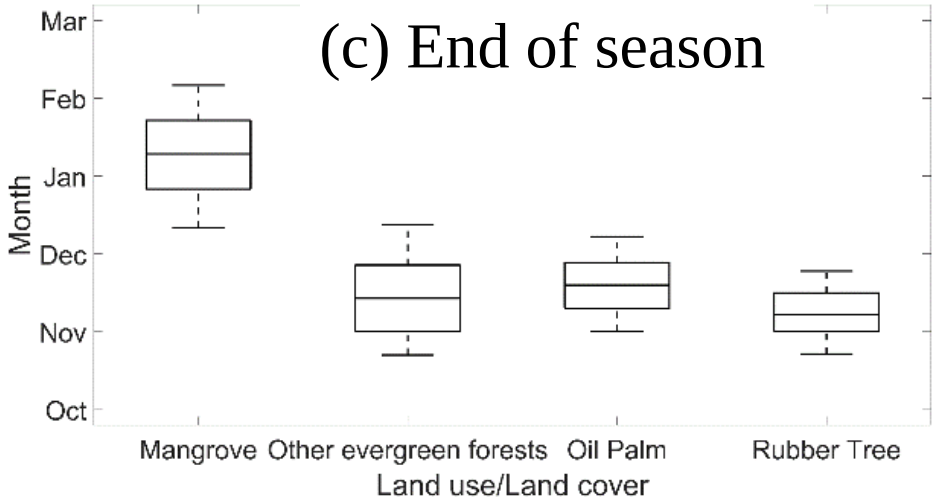
5 Nakhon Si Thammarat

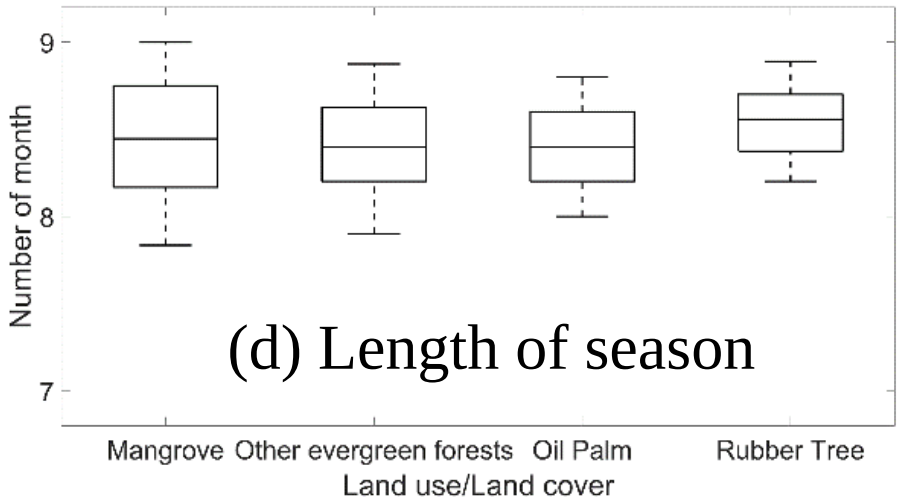


Data source of Land cover/land use type: Land Development Department in 2012









- There are three major land cover/land use types over Southern Thailand.
- Mangrove phenologies were shifted to later in the year by approximately 2 months compared with the land-based tropical forests.
- However, the averaged length of the growing season of the mangroves was quite similar to the land tropical forest, at about 8-9 months duration.

(6) Conclusions

- MODIS EVI has great potential to evaluate mangrove phenology.
- The mangrove growth season was approximately 8–9 months duration, starting in April to June, peaking in August to October and ending in January to February of the following year.
- The mangrove phenologies are difference between the both side of Southern Thailand followed by rainfall seasonal as the main driver.
- Mangrove phenology lagged later with the surrounding tropical forests by about 2 months.

(6) Conclusions

- The 10-year trend analysis revealed significant delaying trends in SOS, POS, and EOS for the Andaman Sea sites but only for EOS at the Gulf of Thailand site.
- The cumulative rainfall is likely to be the main factor driving later mangrove phenologies.


THANK YOU

Lag analysis

Driver Month	EVI Month
1	1
2	2
3	3
4	4
5	5

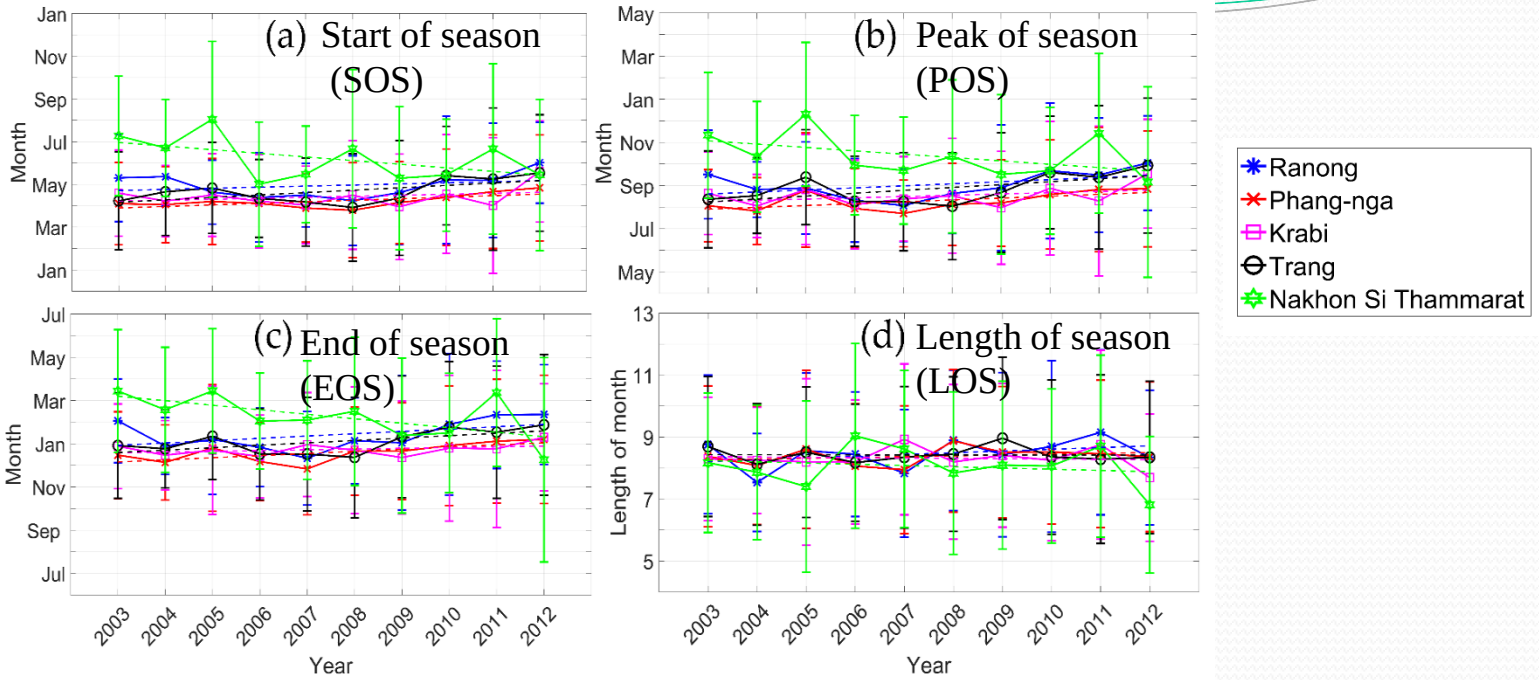
Lag: 1 month

Driver Month	EVI Month
1	2
2	3
3	4
4	5

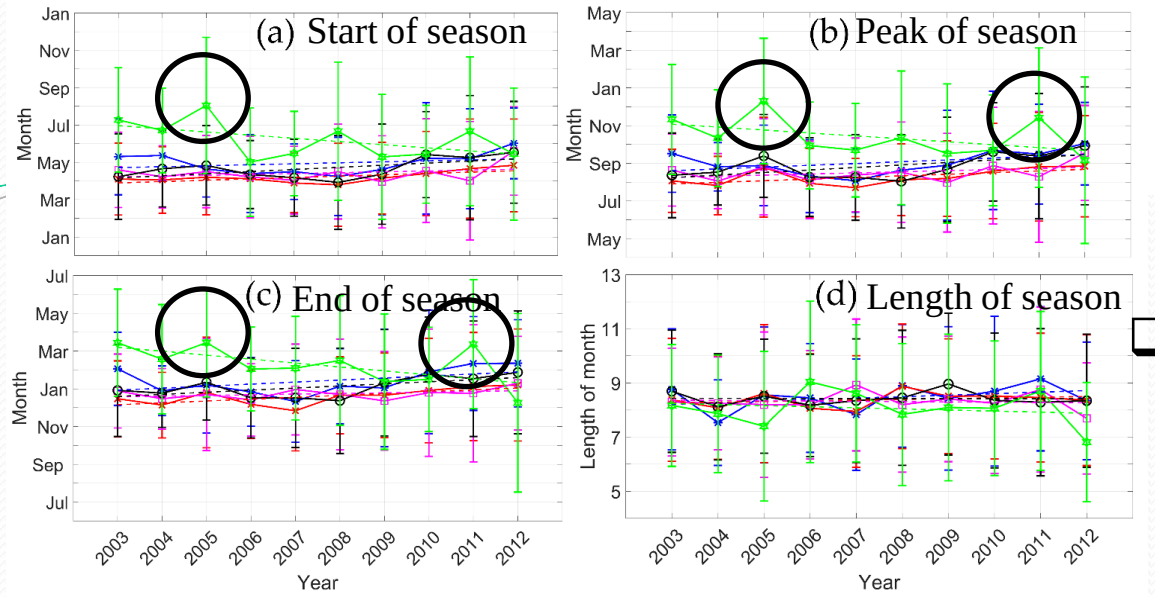
Lag: 2 months

Driver Month	EVI Month
1	3
2	4
3	5

Trend analysis

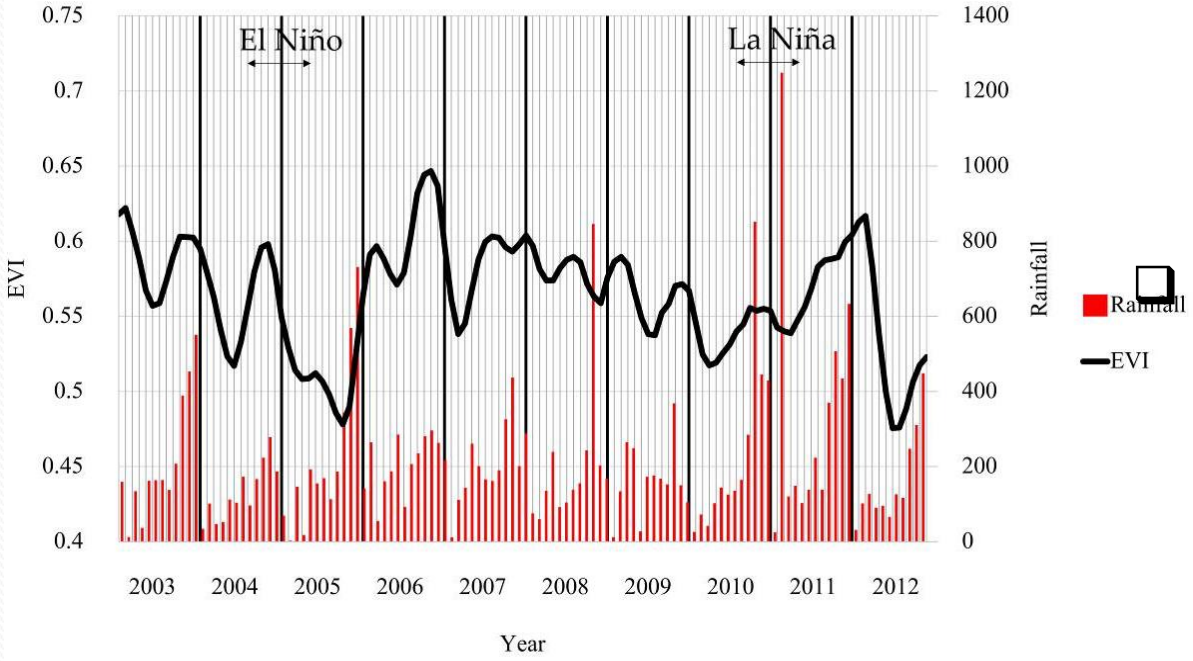


- The significant trend can observed only Phang-nga province site.
- A **delayed trend** of SOS, POS and EOS is +0.072 month/year ($R^2 = 0.446$, $p < 0.05$), +0.086 month/year ($R^2 = 0.359$, $p < 0.1$), and +0.098 month/year ($R^2 = 0.450$, $p < 0.05$), respectively.
- EOS significantly **advanced** at Nakhon Si Thammarat province site (–0.209 month/year, $R^2 = 0.373$, $p < 0.1$).
- There was no statistical trend of LOS vs. time, for all sites through the ten years.



Trend analysis

- **El Niño** (drier than normal) and **La Niña** (wetter than normal) years influenced mangrove phenology, at **Nakhon Si Thammarat province site**
- El Niño in 2004 – 2005: Generally, start of season (SOS) occurred around June/July but SOS in 2005 was delayed to August.
- La Niña at the 2010 – 2011: resulted in a later end of season in April/May, where it generally occurred in February/March.

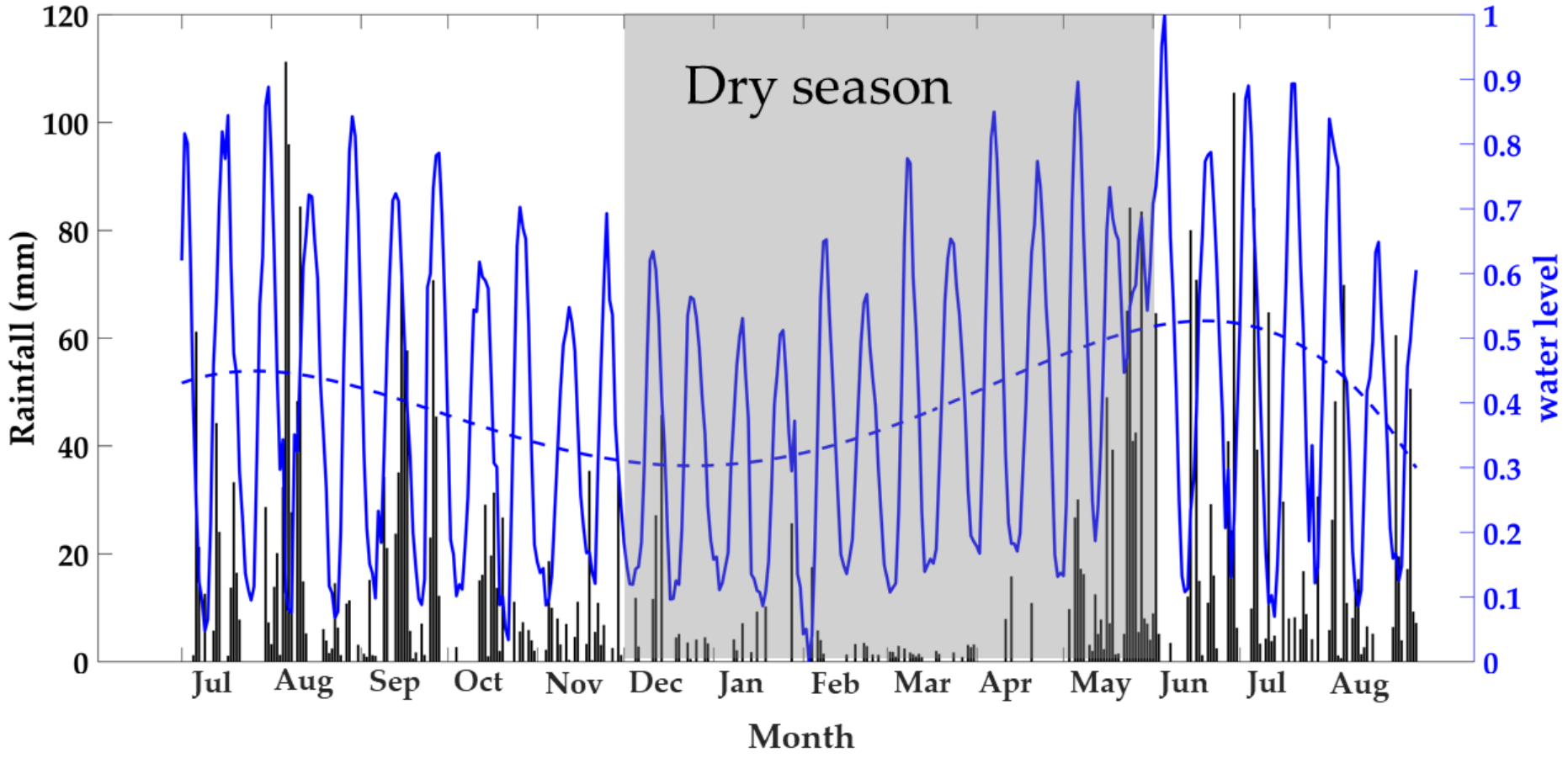


Trend analysis

Site name	Start of season	Peak of season	End of season	Length of season
Ranong	Slope =0.051 R^2 = 0.078	Slope = 0.095 R^2 = 0.210	Slope = 0.107 R^2 = 0.214	Slope = 0.056 R^2 = 0.124
Phang-nga	Slope = 0.072 R^2 = 0.446 **	Slope = 0.086 R^2 = 0.359 *	Slope = 0.098 R^2 = 0.450 **	Slope = 0.026 R^2 = 0.076
Krabi	Slope = 0.046 R^2 = 0.084	Slope = 0.060 R^2 = 0.143	Slope = 0.035 R^2 = 0.145	Slope = –0.011 R^2 = 0.009
Trang	Slope = 0.113 R^2 = 0.367 *	Slope = 0.134 R^2 = 0.369 *	Slope = 0.111 R^2 = 0.379 *	Slope = –0.002 R^2 = 0.0004
Nakhon Si Thammarat	Slope= –0.169 R^2 = 0.256	Slope = –0.156 R^2 = 0.220	Slope = –0.209 R^2 = 0.373*	Slope = –0.04 R^2 = 0.035

Unit of slope: month per year

Note: ** $p < 0.05$, * $p < 0.1$.


Dry season
Rainfall (mm)
water level
Month
120
100
80
60
40
20
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug

1.3 How does phenology study?

Image sources	Crops	Evergreen Broadleaf forest	Tropical forest	Grassland/ Savanna	Mangrove forest
Satellite	✓	✓	✓	✓	Pastor-Guzman et al. (2018)
Phenocam	✓	✓	✓	✓	Xiang et al. (2020)

Pastor-Guzman, J.; Dash, J.; Atkinson, P.M. Remote sensing of mangrove forest phenology and its environmental drivers. *Remote Sens. Environ.* **2018**, 205, 71–84.

Xiang, Q.; Zhou, Y.; Liu, J. Monitoring mangrove phenology using camera images. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, 432.