Satellite observations of Southeast Asia tropical forest responses related to climate seasonality, disturbance, and sun angle geometries

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Certificate of original authorship

I, Ngoc Nguyen Tran, declare that this thesis is submitted in fulfilment of the requirements for the award of the degree of Doctor of Philosophy, in the Faculty of Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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Abbreviations

AMP	Seasonal Amplitude
AVHRR	Advanced Very High Resolution Radiometer
BRDF	Bidirectional Reflectance Distribution Function
CERES	Clouds and the Earth's Radiant Energy System
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CV	Coefficient of Variation
DEM	Digital Elevation Model
DT	Dormancy Time
EGS	End of Greening Season
ENSO	El Niño-Southern Oscillation
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization of the United Nations
GRACE	Gravity Recovery and Climate Experiment
IGBP	International Geosphere-Biosphere Programme
LCT	Land Cover Type
LGS	Length of Greening Season
LST	Land Surface Temperature
MODIS	Moderate resolution Imaging Spectroradiometer

NASA	National Aeronautics and Space Administration
NBAR	Bidirectional reflectance distribution function Adjusted Reflectance
NDVI	Normalized Difference Vegetation Index
NIR	Near Infra-Red
PGS	Peak of Greening Season
QA	Quality assessment
RAA	Relative Azimuth Angle
SEA	Southeast Asia
SGS	Start of Greening Season
SSS	Seasonal Sen's Slope
SZA	Sun Zenith Angle
TRMM	Tropical Rainfall Measuring Mission
TWS	Total Water Storage
TWSA	Total Water Storage Anomalies
USGS	United States Geological Survey
VI	Vegetation Index
VZA	View Zenith Angle

Abstract

A mix of evergreen rainforests and deciduous dry forests, the tropical forests in continental Southeast Asia (SEA) have been massively affected by human activities. Despite being highly threatened, very few studies have been conducted on SEA forests compared to the amount of studies conducted on their Amazonian and African counterparts. Consequently, studies on continental tropical forests in SEA need to be urgently conducted to gain a better understanding of their functioning and more specifically, their seasonal and inter-annual dynamics. Satellite data have proven useful in monitoring vegetated landscapes at variable spatial and temporal scales; however, variations of sun-sensor geometry have caused controversies over satellite-based results. Thus, the effect of variable sun-view angles on phenology needs to be investigated to minimise observation artefacts from real vegetation seasonal dynamics.

The primary goal of this thesis is to study the inter- and intra-annual dynamics of continental SEA tropical forests using vegetation indices (VIs) derived from MODIS satellite data while also considering the effects of the bidirectional reflectance distribution function (BRDF) on the retrieved results. To achieve this goal, I first investigated continental SEA forest phenology and the effects of the BRDF on extracted phenological information. Next, I analysed the disturbance contribution in relation to intra-annual forest phenology by comparing seasonal profiles and phenological metrics between disturbed and undisturbed forests. Finally, I analysed the effects of the BRDF on the inter-annual VI variations and the inter-annual responses of SEA forests to climate variability.

The results showed that the BRDF had substantial effects on the retrieved VI data. Thus, it appears that standardising reflectances and VIs at fixed sun-view angles is an essential process in the analysis of tropical forest phenology in the continental SEA region. Correcting the BRDF will prevent any unnecessary controversy in relation to the effects of varying illumination angles and the viewing geometries of satellite-based observations. Regarding the disturbance effects, my findings showed that disturbance affected SEA forest phenology in terms of both seasonal VI profiles and phenological metrics and that the BRDF correction helped to distinguish between disturbed and intact forests. My analyses also revealed that the inter-annual VI variations of SEA forests were affected by both the BRDF effect and climate variability.

This thesis highlights the responses of continental SEA tropical forests to sun-angle geometries, climate seasonality and disturbances related to satellite observations. It makes an essential and significant contribution to understandings of SEA forest phenological diversity.