Spatiotemporal dynamics of dryland vegetation photosynthesis and greenness under hydroclimatic extremes

by Song Leng

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under the supervision of Prof. Alfredo Huete

University of Technology Sydney

Faculty of Science

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Publications

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Abbreviations

AI	Aridity Index
AU-ASM	Alice Springs Mulga
AU-Dry	Dry River
AU-How	Howard Springs
AU-Stp	Sturt Plains
AU-TTE	Ti Tree East
CERES	Cloud and Earth's Radiant Energy System
CPA	Cumulative Precipitation Anomalies
DJF	December-January-February
DLCD	Dynamic Land Cover Dataset
DOY	Day of Year
ENSO	El Niño-Southern Oscillation
ESA	European Space Agency
EVI	Enhanced Vegetation Index
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
fPAR	Fraction of Photosynthetically Active Radiation
GOME-2	Global Ozone Monitoring Experiment-2
GOSAT	Greenhouse Gases Observing Satellite
GPP	Gross Primary Productivity
GRACE	Gravity Recovery and Climate Experiment

IMERG	Integrated Multi-Satellite Retrievals for Global Precipitation Measurement
LAI	Leaf Area Index
LSP	Land Surface Phenology
LST	Land Surface Temperature
LUE	Light Use Efficiency
MVGs	Major Vegetation Groups
NASA	National Aeronautics and Space Administration
NATT	North Australian Tropical Transect
NDVI	Normalized Difference Vegetation Index
NEP	Net Ecosystem Production
NIR	Near Infra-Red
NVIS	National Vegetation Information System
OCO-2	Orbiting Carbon Observatory-2
PAR	Photosynthetically Active Radiation
PET	Potential Evapotranspiration
POS	Peak of Growing Season
RAU	Rate of Autumn Senescence
ROI	Region of Interest
RSP	Rate of Spring Green-up
SA	Standardized Anomaly
SD	Standard Deviation
SIF	Sun-Induced chlorophyll Fluorescence
SM	Soil Moisture
SOS	Start of Growing Season
SPEI	Standardized Precipitation Evapotranspiration Index
TPs	Test-pixels
TRMM	Tropical Rainfall Measuring Mission

TROPOMI	TROPOspheric Monitoring Instrument
TWSA	Total Water Storage Anomaly
VI	Vegetation Indices
VPD	Vapour Pressure Deficit
WUE	Water-Use Efficiency

Abstract

Australia's dryland ecosystems play a critical role in regulating the climate system and considerably influence the interannual variability in global carbon cycle. However, the dynamics of dryland vegetation under climate variability and extreme events have not been as thoroughly investigated as in other ecosystems. Spaceborne solar-induced chlorophyll fluorescence (SIF) provide a fresh means to evaluate vegetation photosynthetic activity and detect vegetation stress. Considering its spatially coarse resolution, studies with reference to the application of SIF over heterogeneous dryland ecosystem are rarely reported.

The main goal of this thesis is to explore the spatial and temporal dynamics of Australia's dryland vegetation under hydro-climatic extremes using satellite-estimated fluorescence and greenness. To achieve this goal, I first utilized a strong wet pulse in 2016-2017 as well as in the 2011 big wet period as natural experiments to assess the response of major dryland biomes in central Australia. Next, I investigated the impact of a recent extreme drought on spatiotemporal variability of Australia's dryland vegetation indicated by multi-source satellite-based SIF. Finally, I analysed the spatial pattern and seasonal variations in dryland vegetation phenology under climate variability.

The results showed semiarid ecosystems to have the largest variability and were most sensitive to climate extremes. SIF derived from the Global Ozone

Monitoring Experiment-2 (GOME-2) at 0.5° spatial resolution has an insufficient capacity for capturing spatiotemporal dynamics over xeric central Australia as a result of low signal level and high retrieval noise. In contrast to humid ecosystems, both SIF and enhanced vegetation index (EVI) simultaneously captured the declines of arid/semiarid plant growth from the beginning of extreme drought events at 16-day scale. SIF data retrieved from TROPOspheric Monitoring Instrument (TROPOMI) at a 0.05° spatial grid exhibits promising capability of mapping and characterizing the dynamics of heterogeneous dryland vegetation in future.

This thesis highlights that the incorporation of satellite-observed greenness and fluorescence can potentially contribute to an improved understanding of dryland vegetation dynamics and can advance our ability to detect ecosystem alterations under future changing climates.