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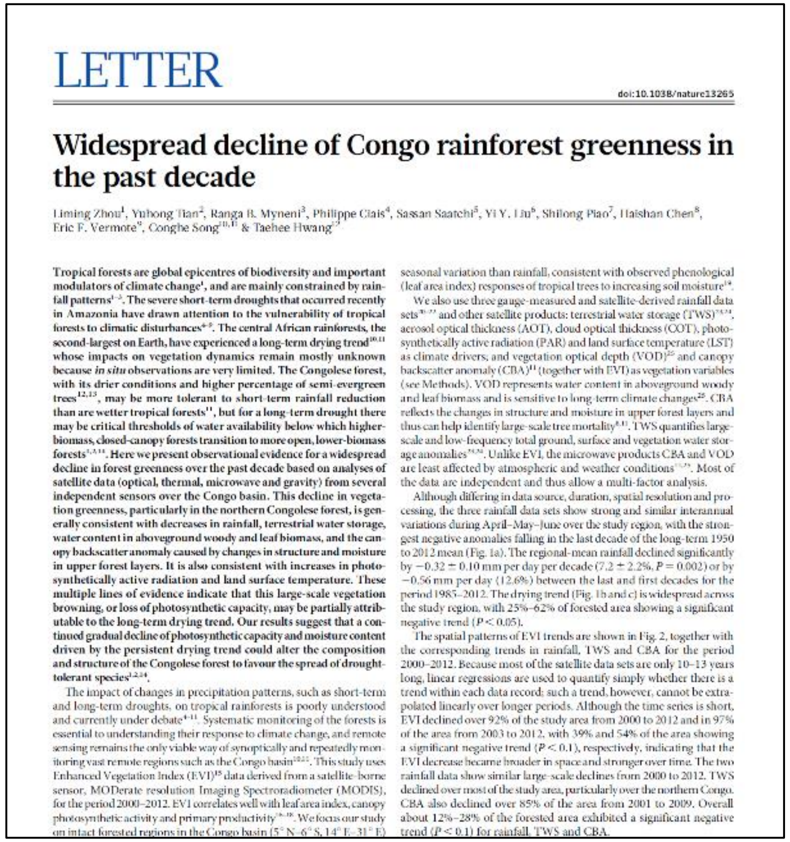
SEARCHING FOR SATELLITE SIGNALS OF FOREST STABILITY

THOMAS A. GROEN WITH CONTRIBUTIONS FROM INKA DIATMIKO, GOHAR SHAHINYAN, DAN KANMEGNE, KRISHNA LAMSAL,

NIINA RAUTIAINEN, BABAK NAIMI, KOEN DE KONING, SARA ALIBAKSI, FATEMEH MAHMOUDI AND ANTON VRIELING

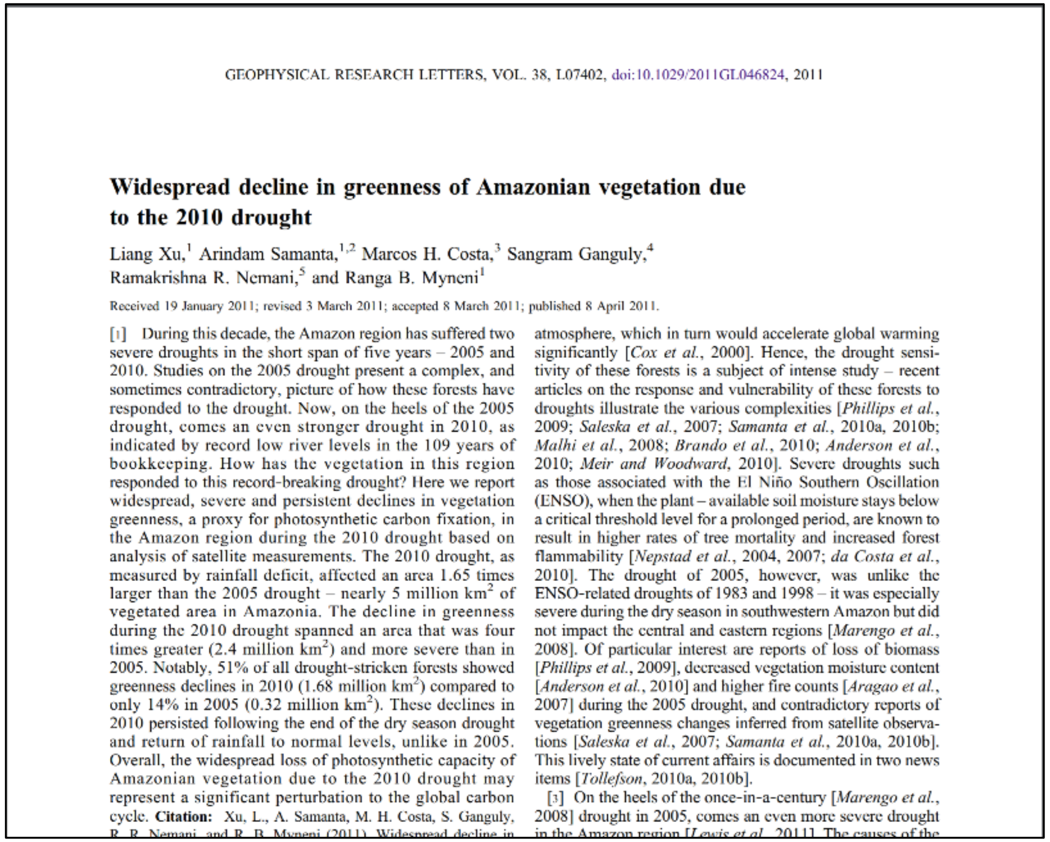
WHY LOOK AT FOREST STABILITY?


LETTER

doi:10.1038/nature13265

Widespread decline of Congo rainforest greenness in the past decade

Liming Zhou[1], Yuhong Tian[2], Ranga B. Myneni[3], Philippe Ciais[4], Sassan Saatchi[5], Yi Y. Liu[6], Shilong Piao[7], Haishan Chen[8], Eric F. Vermote[9], Conghe Song[10,11] & Taehee Hwang[12]


GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L07402, doi:10.1029/2011GL046824, 2011

Widespread decline in greenness of Amazonian vegetation due to the 2010 drought

Liang Xu,[1] Arindam Samanta,[1,2] Marcos H. Costa,[3] Sangram Ganguly,[4] Ramakrishna R. Nemani,[5] and Ranga B. Myneni[1]

Received 19 January 2011; revised 3 March 2011; accepted 8 March 2011; published 8 April 2011.

[1] During this decade, the Amazon region has suffered two severe droughts in the short span of five years – 2005 and 2010. Studies on the 2005 drought present a complex, and sometimes contradictory, picture of how these forests have responded to the drought. Now, on the heels of the 2005 drought, comes an even stronger drought in 2010, as indicated by record low river levels in the 109 years of bookkeeping. How has the vegetation in this region responded to this record-breaking drought? Here we report widespread, severe and persistent declines in vegetation greenness, a proxy for photosynthetic carbon fixation, in the Amazon region during the 2010 drought based on analysis of satellite measurements. The 2010 drought, as measured by rainfall deficit, affected an area 1.65 times larger than the 2005 drought – nearly 5 million km^2 of vegetated area in Amazonia. The decline in greenness during the 2010 drought spanned an area that was four times greater (2.4 million km^2) and more severe than in 2005. Notably, 51% of all drought-stricken forests showed greenness declines in 2010 (1.68 million km^2) compared to only 14% in 2005 (0.32 million km^2). These declines in 2010 persisted following the end of the dry season drought and return of rainfall to normal levels, unlike in 2005. Overall, the widespread loss of photosynthetic capacity of Amazonian vegetation due to the 2010 drought may represent a significant perturbation to the global carbon cycle. **Citation:** Xu, L., A. Samanta, M. H. Costa, S. Ganguly, R. R. Nemani, and R. B. Myneni (2011), Widespread decline in

atmosphere, which in turn would accelerate global warming significantly [*Cox et al.*, 2000]. Hence, the drought sensitivity of these forests is a subject of intense study – recent articles on the response and vulnerability of these forests to droughts illustrate the various complexities [*Phillips et al.*, 2009; *Saleska et al.*, 2007; *Samanta et al.*, 2010a, 2010b; *Malhi et al.*, 2008; *Brando et al.*, 2010; *Anderson et al.*, 2010; *Meir and Woodward*, 2010]. Severe droughts such as those associated with the El Niño Southern Oscillation (ENSO), when the plant – available soil moisture stays below a critical threshold level for a prolonged period, are known to result in higher rates of tree mortality and increased forest flammability [*Nepstad et al.*, 2004, 2007; *da Costa et al.*, 2010]. The drought of 2005, however, was unlike the ENSO-related droughts of 1983 and 1998 – it was especially severe during the dry season in southwestern Amazon but did not impact the central and eastern regions [*Marengo et al.*, 2008]. Of particular interest are reports of loss of biomass [*Phillips et al.*, 2009], decreased vegetation moisture content [*Anderson et al.*, 2010] and higher fire counts [*Aragao et al.*, 2007] during the 2005 drought, and contradictory reports of vegetation greenness changes inferred from satellite observations [*Saleska et al.*, 2007; *Samanta et al.*, 2010a, 2010b]. This lively state of current affairs is documented in two news items [*Tollefson*, 2010a, 2010b].

[3] On the heels of the once-in-a-century [*Marengo et al.*, 2008] drought in 2005, comes an even more severe drought in the Amazon region [*Lewis et al.*, 2011]. The causes of the

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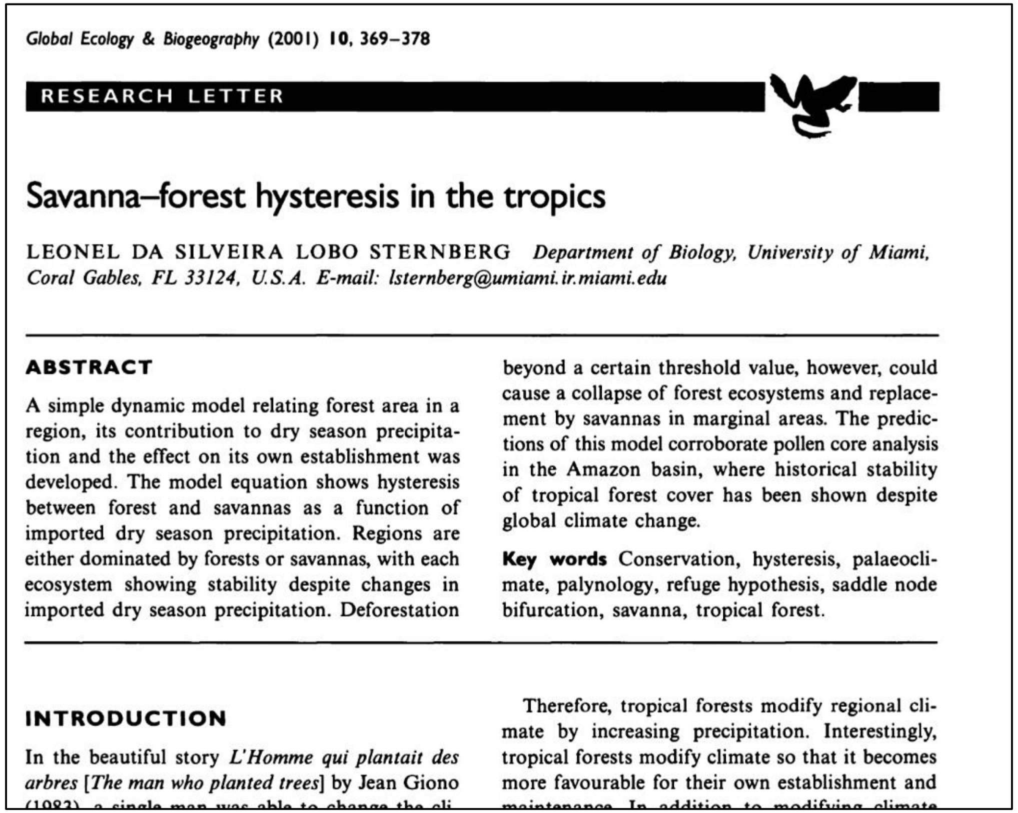
WHY LOOK AT FOREST STABILITY?



Global Ecology & Biogeography (2001) **10**, 369–378

RESEARCH LETTER

Savanna–forest hysteresis in the tropics

LEONEL DA SILVEIRA LOBO STERNBERG *Department of Biology, University of Miami, Coral Gables, FL 33124, U.S.A. E-mail: lsternberg@umiami.ir.miami.edu*

ABSTRACT

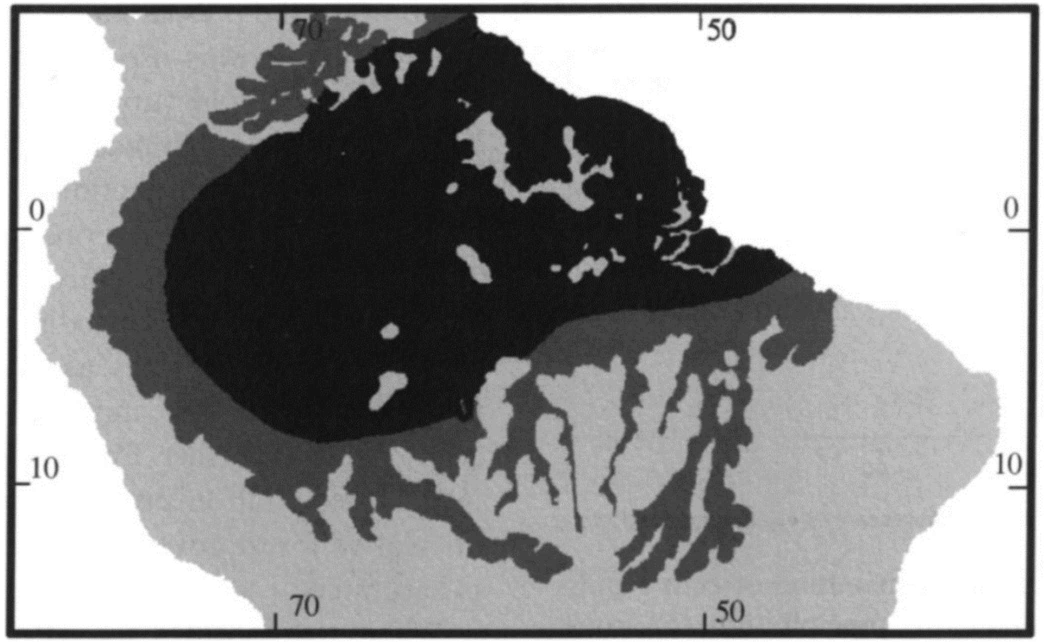
A simple dynamic model relating forest area in a region, its contribution to dry season precipitation and the effect on its own establishment was developed. The model equation shows hysteresis between forest and savannas as a function of imported dry season precipitation. Regions are either dominated by forests or savannas, with each ecosystem showing stability despite changes in imported dry season precipitation. Deforestation beyond a certain threshold value, however, could cause a collapse of forest ecosystems and replacement by savannas in marginal areas. The predictions of this model corroborate pollen core analysis in the Amazon basin, where historical stability of tropical forest cover has been shown despite global climate change.

Key words Conservation, hysteresis, palaeoclimate, palynology, refuge hypothesis, saddle node bifurcation, savanna, tropical forest.

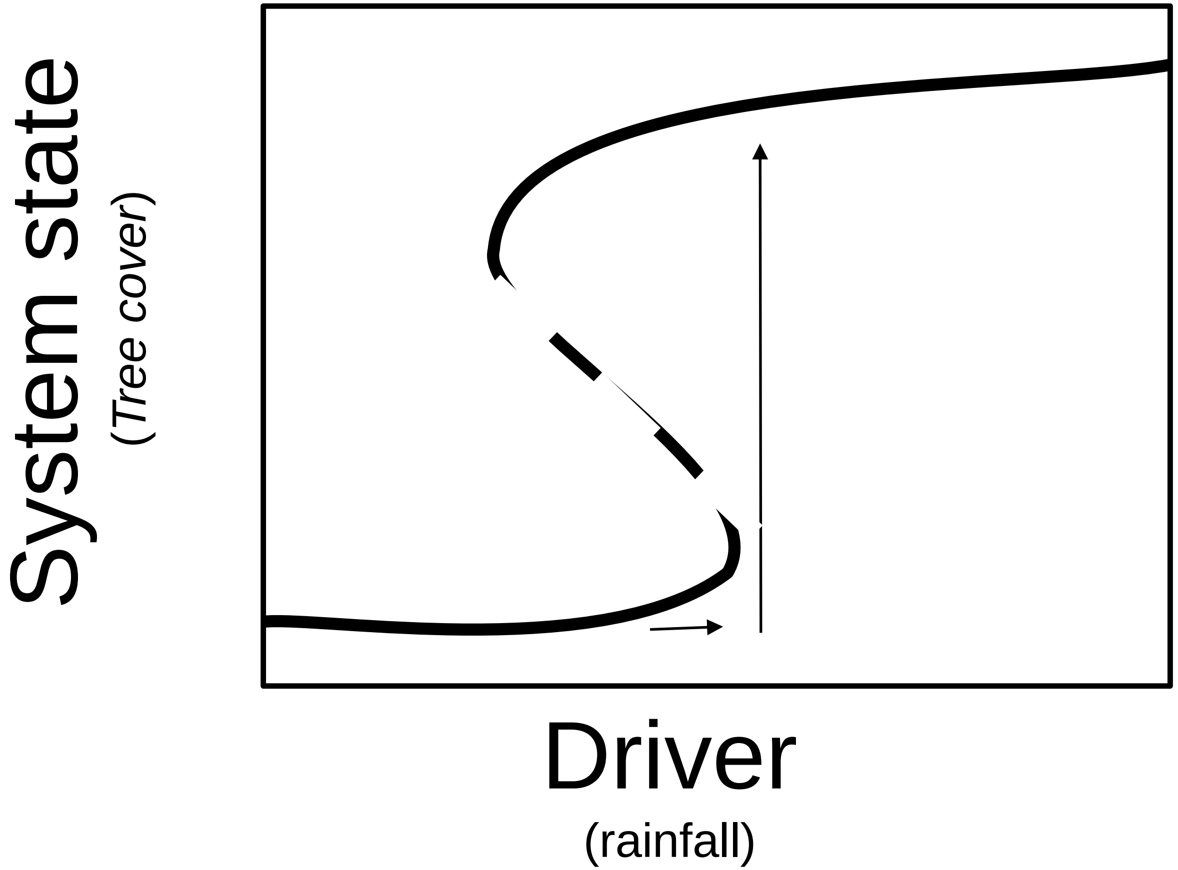
INTRODUCTION

In the beautiful story *L'Homme qui plantait des arbres* [*The man who planted trees*] by Jean Giono

Therefore, tropical forests modify regional climate by increasing precipitation. Interestingly, tropical forests modify climate so that it becomes more favourable for their own establishment and

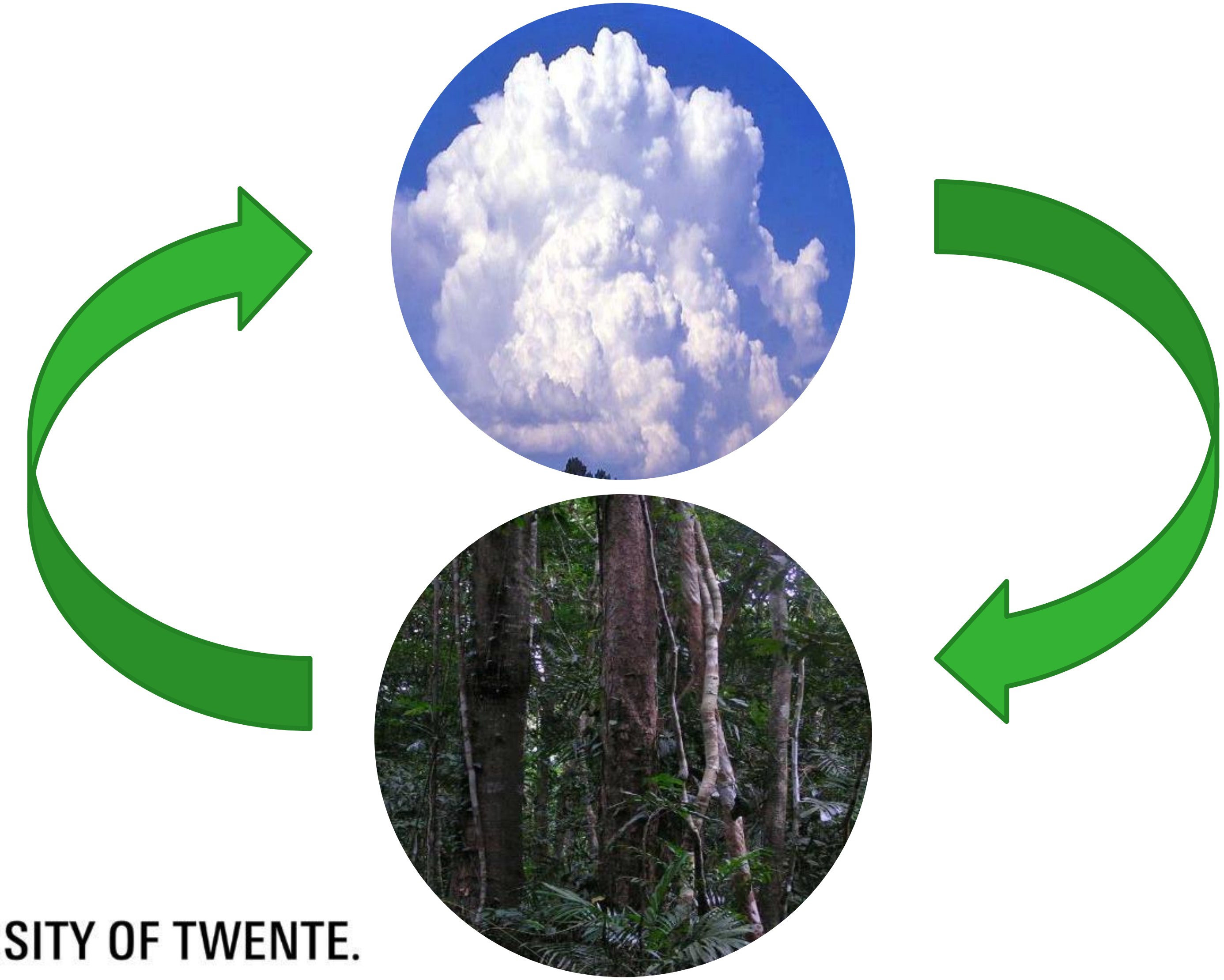


WHAT IS HYSTERESIS?

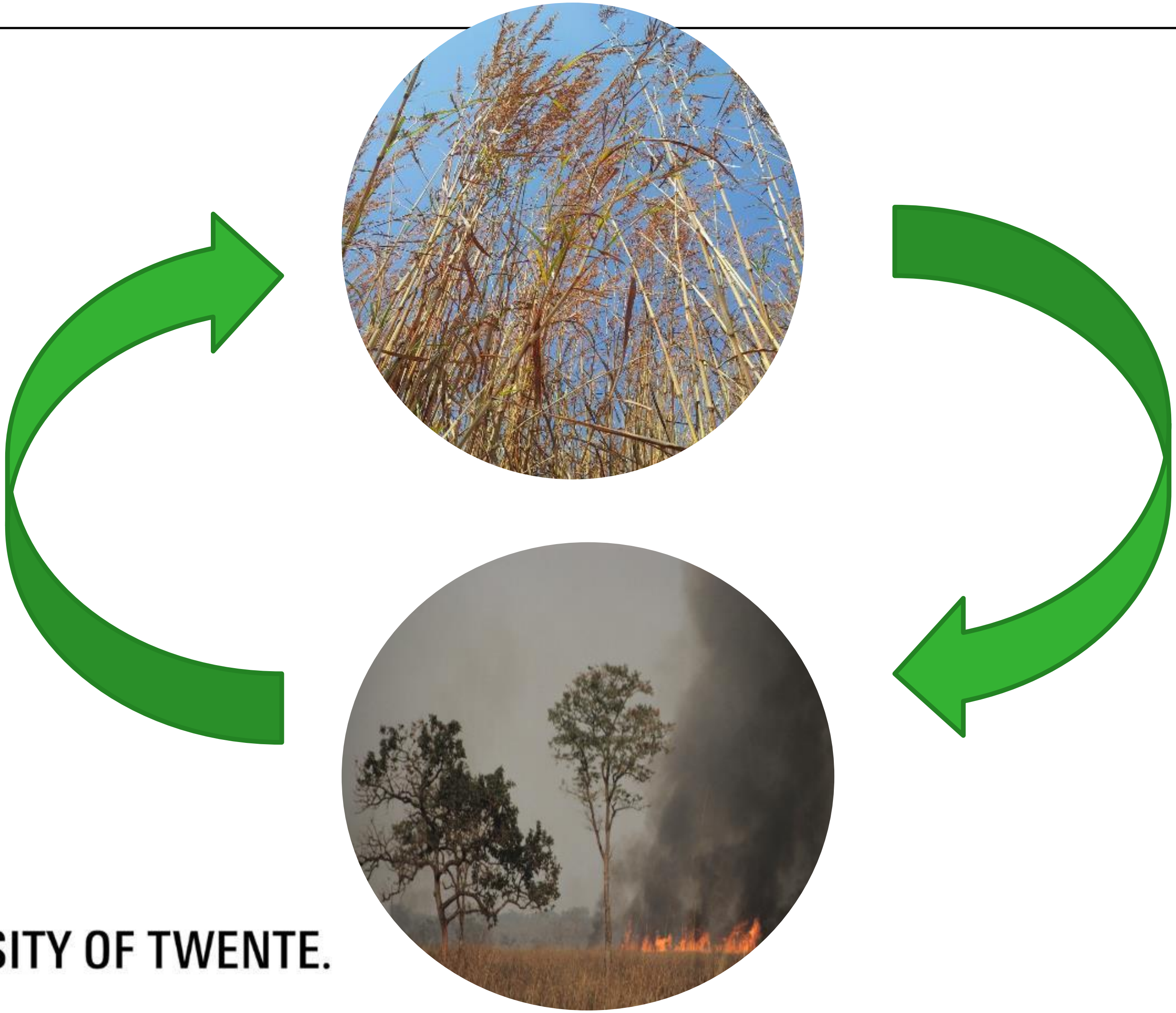


Images: http://www.taekwondo-reza.at/chagi.html

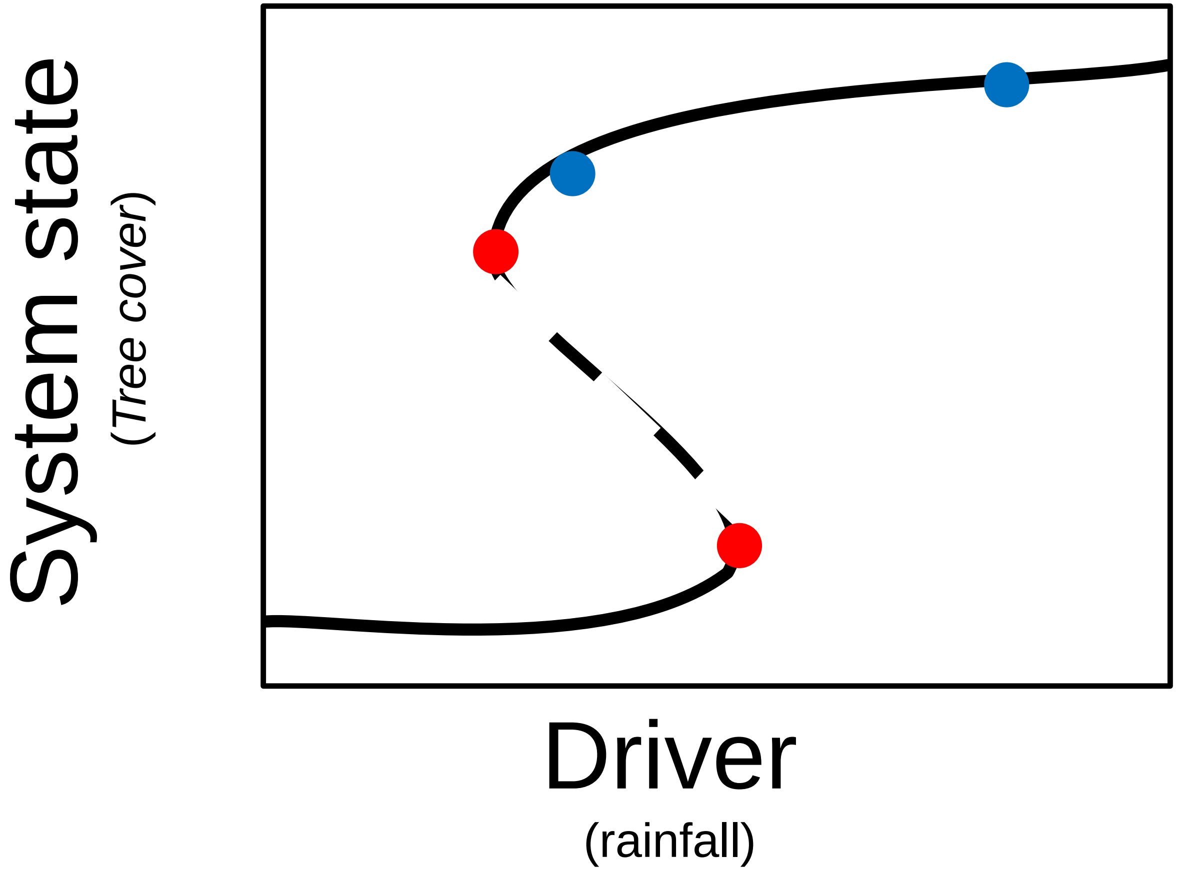
A POSITIVE FEEDBACK LOOP EXISTS IN THIS SYSTEM...



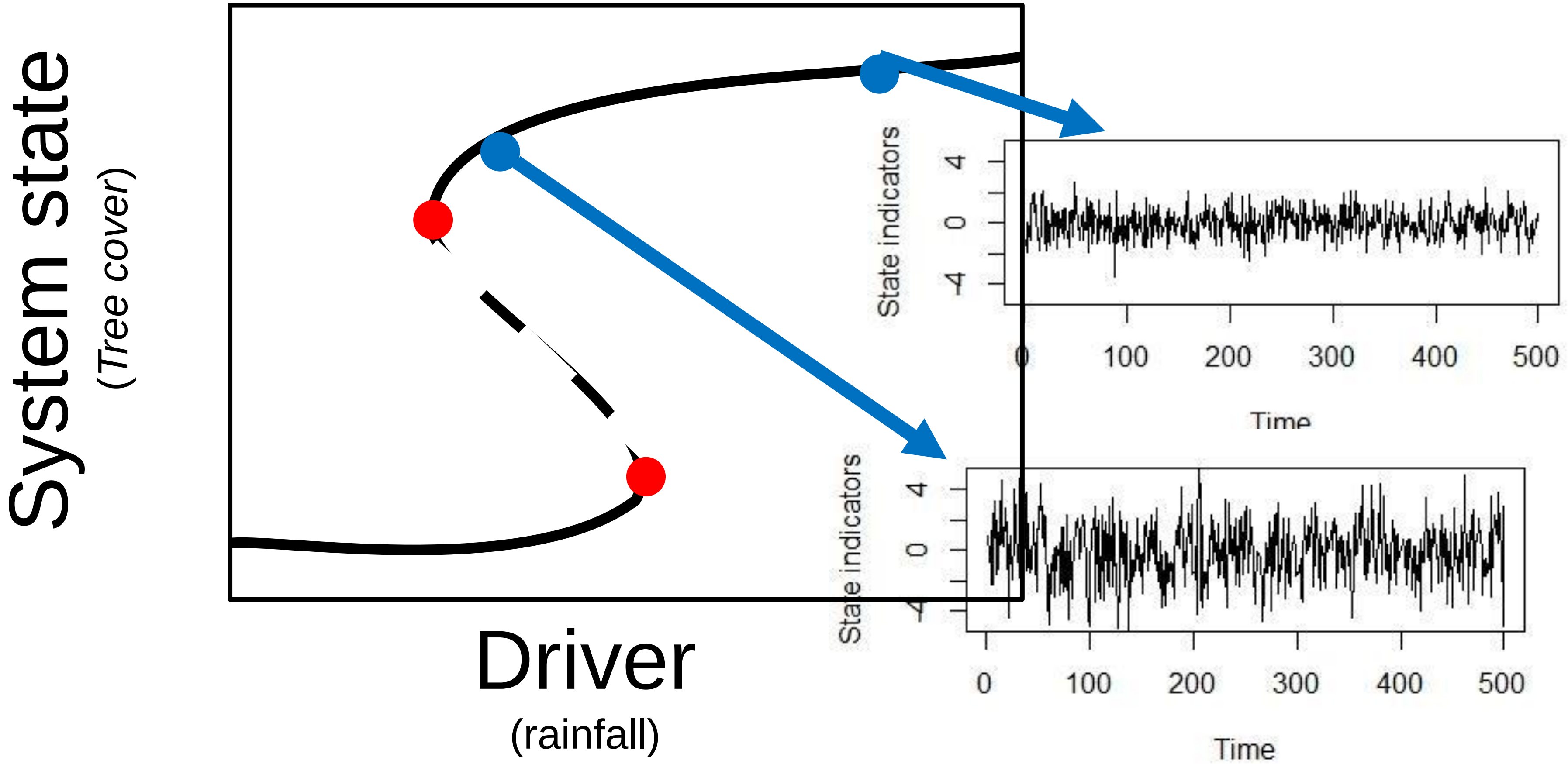
...AND ANOTHER ONE



HOW TO DETECT PROXIMITY TO TIPPING POINTS



HOW TO DETECT PROXIMITY TO TIPPING POINTS



EARLY WARNING INDICATORS FOR TIPPING POINTS

OPEN ACCESS Freely available online PLoS one

Methods for Detecting Early Warnings of Critical Transitions in Time Series Illustrated Using Simulated Ecological Data

Vasilis Dakos[1,2]*, Stephen R. Carpenter[3], William A. Brock[4], Aaron M. Ellison[5], Vishwesha Guttal[6], Anthony R. Ives[7], Sonia Kéfi[8], Valerie Livina[9], David A. Seekell[10], Egbert H. van Nes[1], Marten Scheffer[1]

1 Department of Aquatic Ecology and Water Quality Management, Wageningen University, Wageningen, The Netherlands, **2** Integrative Ecology Group, Estación Biológica de Doñana, Sevilla, Spain, **3** Center for Limnology, University of Wisconsin, Madison, Wisconsin, United States of America, **4** Department of Economics, University of Wisconsin, Madison, Wisconsin, United States of America, **5** Harvard Forest, Harvard University, Petersham, Massachusetts, United States of America, **6** Centre for Ecological Sciences, Indian Institute of Science, Bangalore, India, **7** Department of Zoology, University of Wisconsin, Madison, Wisconsin, United States of America, **8** Institut des Sciences de l'Evolution, CNRS, Université de Montpellier II, Montpellier, France, **9** School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom, **10** Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, United States of America

Abstract

Many dynamical systems, including lakes, organisms, ocean circulation patterns, or financial markets, are now thought to have tipping points where critical transitions to a contrasting state can happen. Because critical transitions can occur unexpectedly and are difficult to manage, there is a need for methods that can be used to identify when a critical transition is approaching. Recent theory shows that we can identify the proximity of a system to a critical transition using a variety of so-called 'early warning signals', and successful empirical examples suggest a potential for practical applicability. However, while the range of proposed methods for predicting critical transitions is rapidly expanding, opinions on their practical use differ widely, and there is no comparative study that tests the limitations of the different methods to identify approaching critical transitions using time-series data. Here, we summarize a range of currently available early warning methods and apply them to two simulated time series that are typical of systems undergoing a critical transition. In addition to a methodological guide, our work offers a practical toolbox that may be used in a wide range of fields to help detect early warning signals of critical transitions in time series data.

Citation: Dakos V, Carpenter SR, Brock WA, Ellison AM, Guttal V, et al. (2012) Methods for Detecting Early Warnings of Critical Transitions in Time Series Illustrated Using Simulated Ecological Data. PLoS ONE 7(7): e41010. doi:10.1371/journal.pone.0041010

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Competing Interests: The authors have declared that no competing interests exist.

* E-mail: vasilis.dakos@gmail.com

Introduction

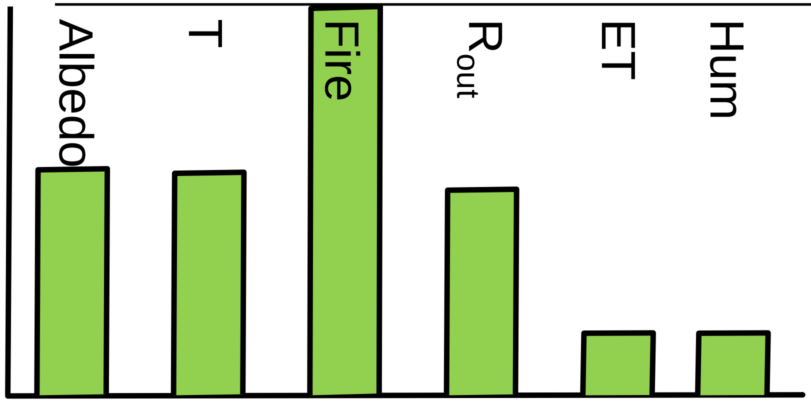
The Earth's past has been characterized by rapid and often unexpected punctuated shifts in temperature and climatic conditions [1], lakes and coral reefs have shifted among alternative

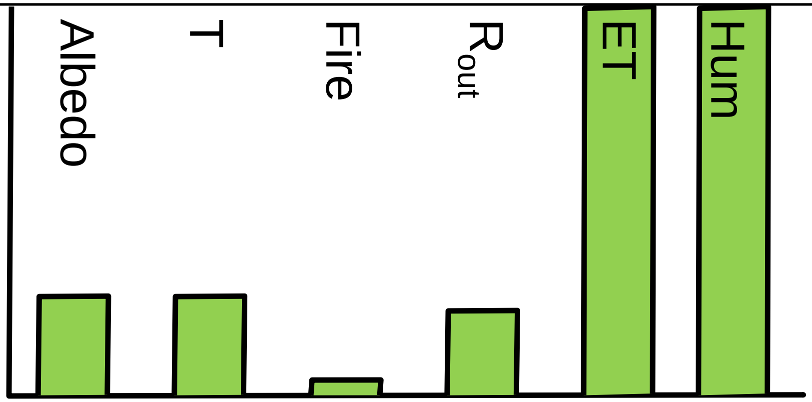
To overcome these challenges, numerous studies have suggested the use of generic early warning signals (or *leading indicators*) that can detect the proximity of a system to a tipping point [6]. Such indicators are based on common mathematical properties of

Table 1. Early warning signals for critical transitions.

	Method/Indicator	Phenomenon: Rising memory	Rising variability	Flickering
metrics	Autocorrelation at-lag-1	x		
	Autoregressive coefficient of AR(1) model	x		
	Return rate (inverse of AR(1) coefficient)	x		
	Detrended fluctuation analysis indicator	x		
	Spectral density	x		
	Spectral ratio (of low to high frequencies)	x		
	Spectral exponent	x		
	Standard deviation		x	x
	Coefficient of variation		x	x
	Skewness		x	x
	Kurtosis		x	x
	Conditional heteroskedasticity		x	x
	BDS test		x	x
models	Time-varying AR(p) models	x	x	
	Nonparametric drift-diffusion-jump models	x	x	x
	Threshold AR(p) models			x
	Potential analysis (potential wells estimator)			x

FOREST AND SAVANNAS: HOW TO ASSESS THEIR STATE





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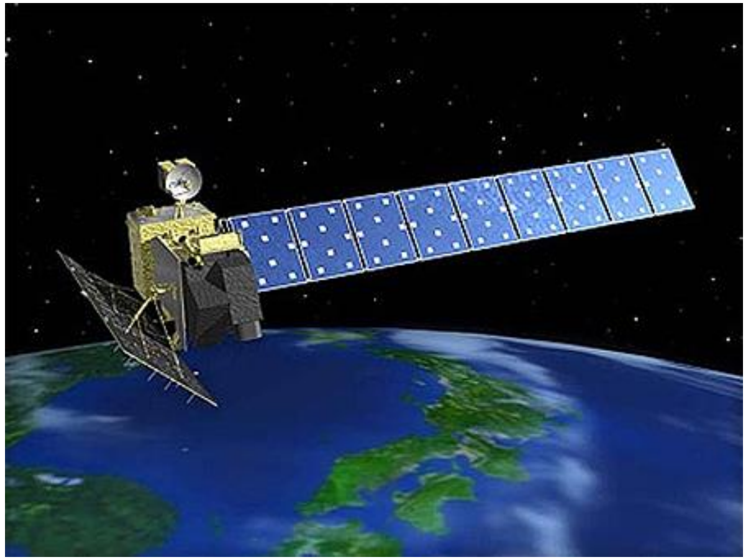
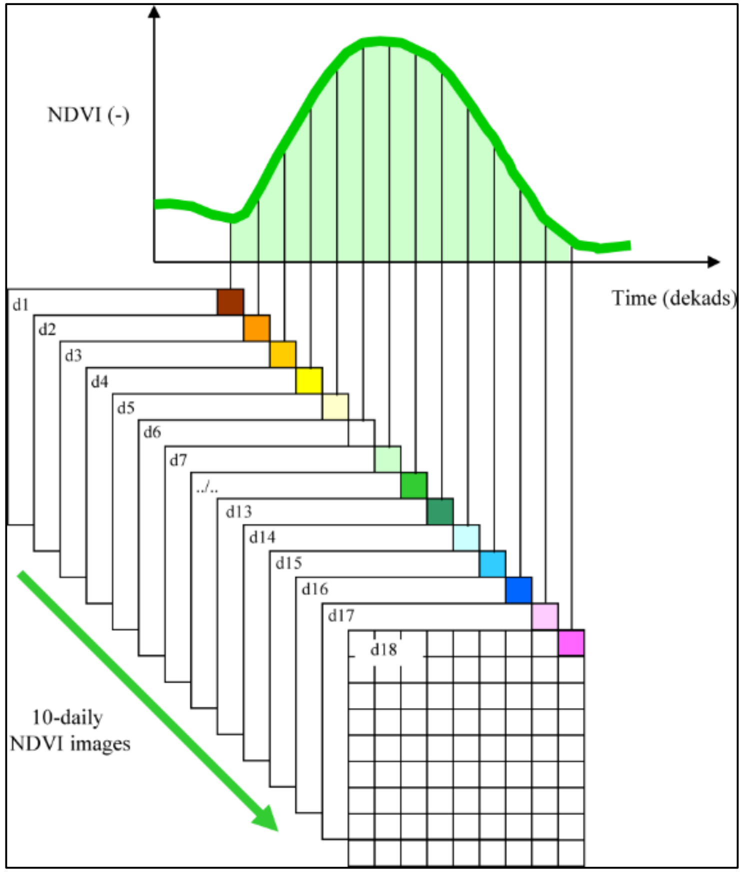
THIS IS WHERE EO ENTERS…





WHAT DO WE NEED FOR THIS DETECTION METHOD

THINKING OF REMOTE SENSING

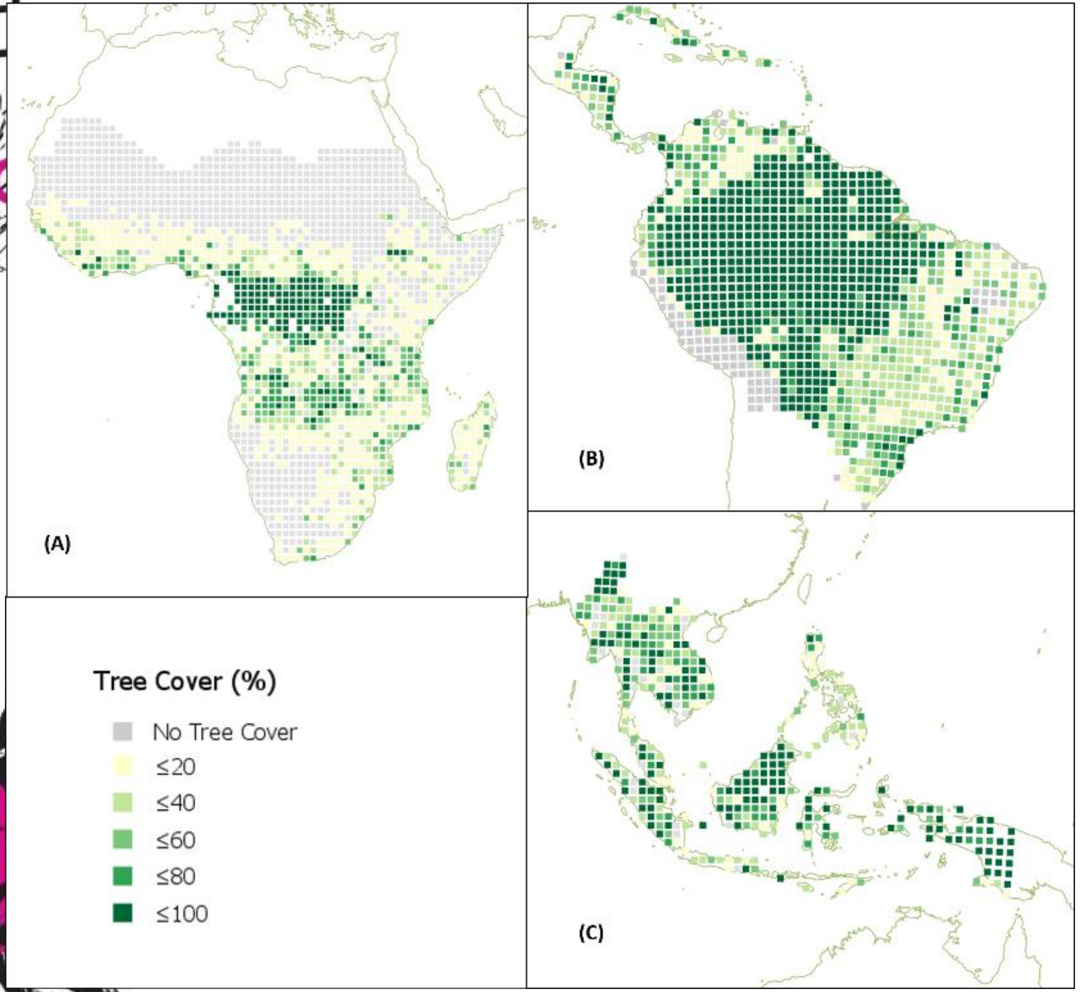
- Continuous time series of observations
- Of sufficient duration
- High frequency
- Measuring a relevant quantity
- At the right spatial scale

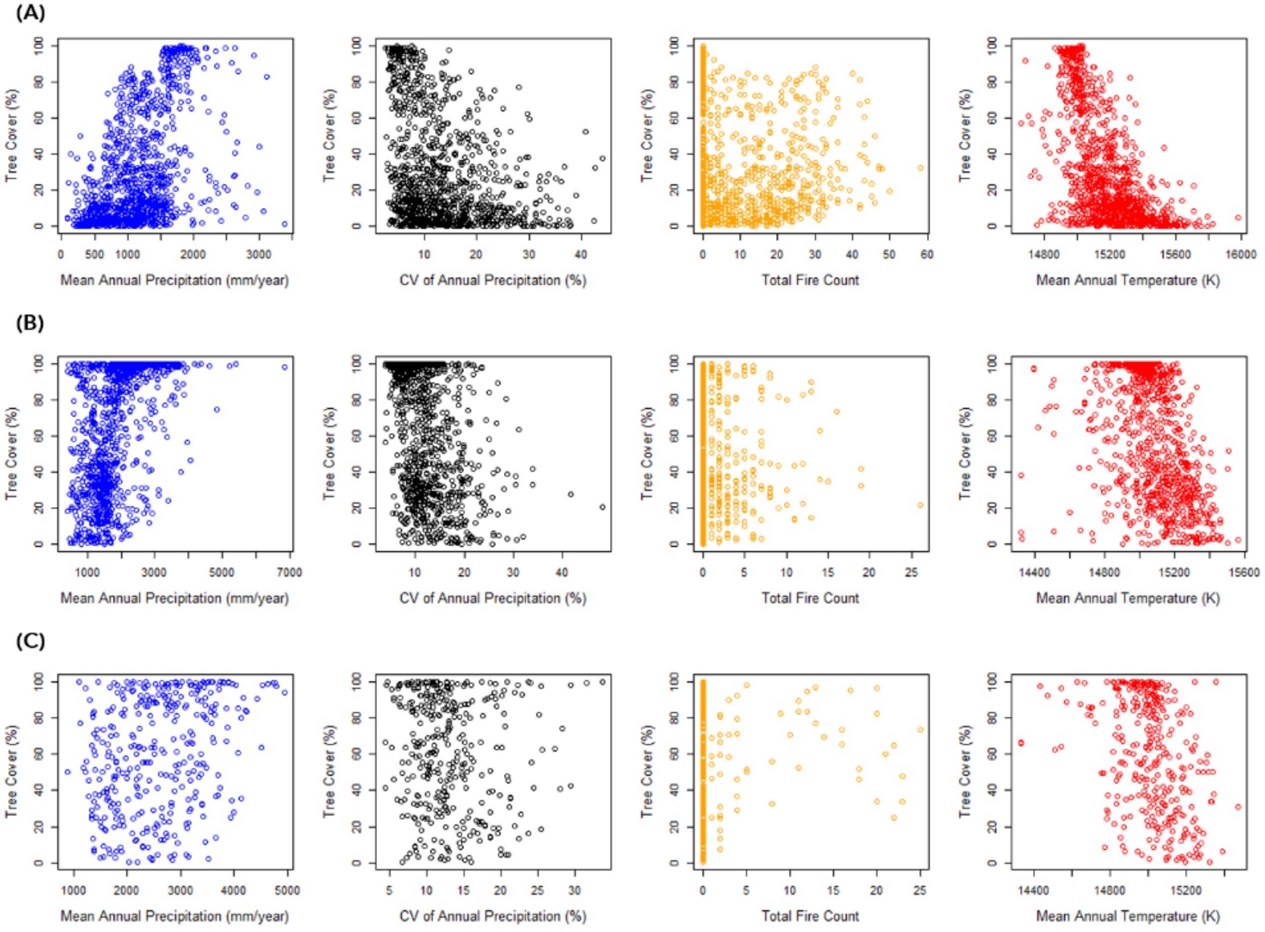
TWO POSSIBLE APPROACHES

- Top Down

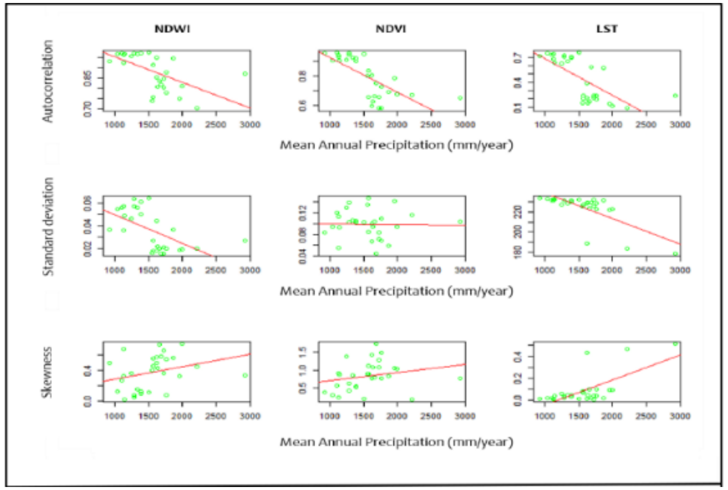
- Bottom Up

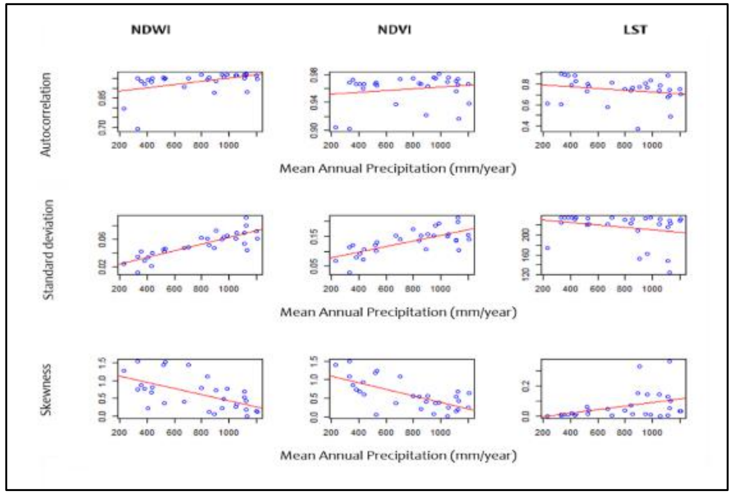
ARE THERE SIGNS OF BISTABILITY?

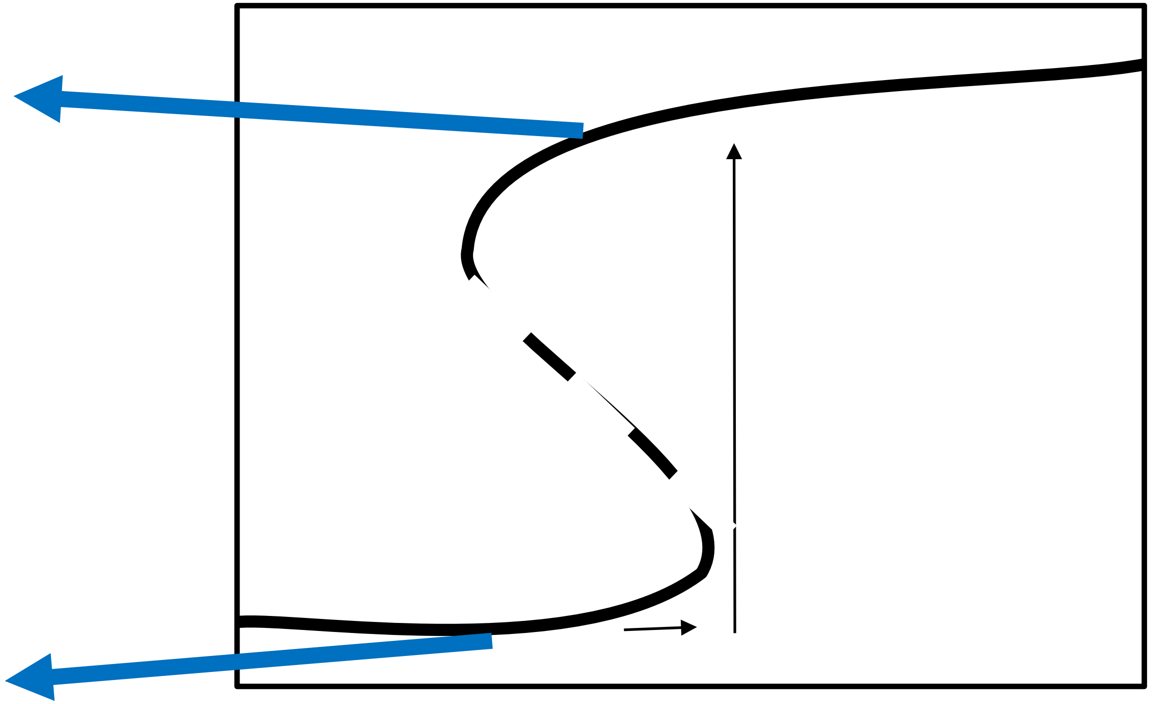




DO TIME SERIES BEHAVE AS WOULD BE EXPECTED?







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STABILITY DETECTION WITH RS


remote sensing MDPI

Article

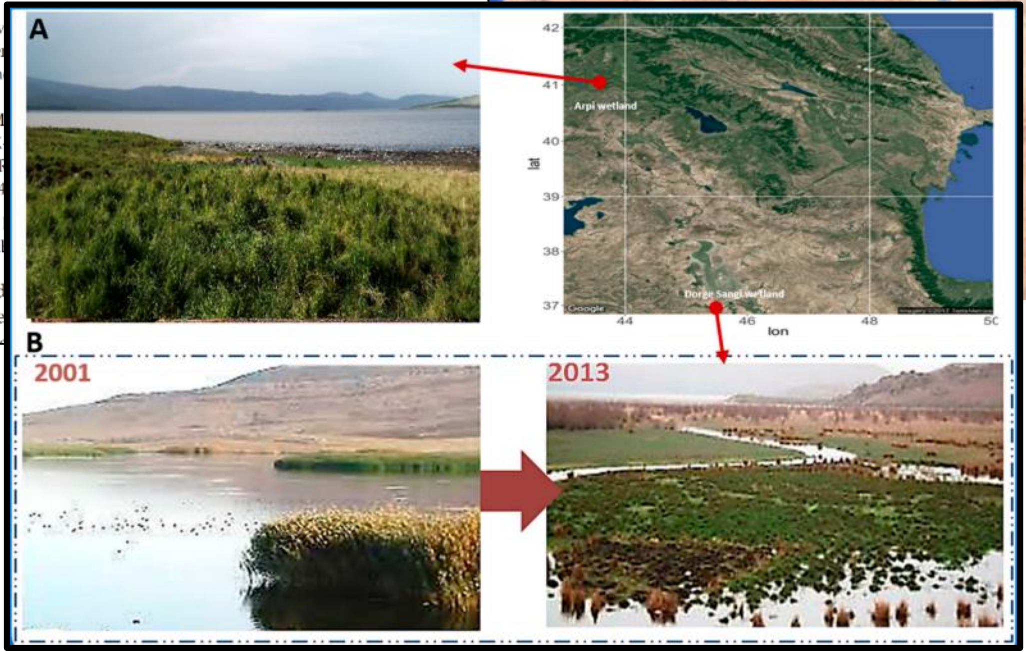
Remotely-Sensed Early Warning Signals of a Critical Transition in a Wetland Ecosystem

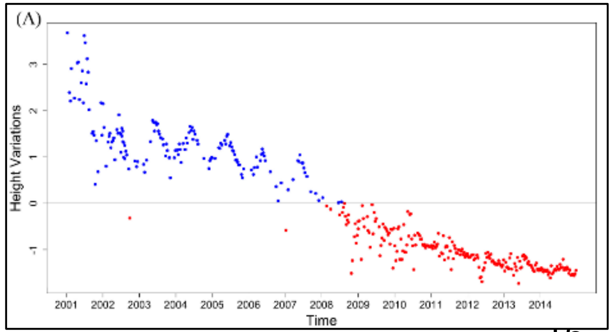
Sara Alibakhshi [1,*], Thomas A. Groen [2], Miina Rautiainen [1,3] and Babak Naimi [4,5]

1 Department of Built Environment, School of Engineering, Aalto University, P.O. Box 14100, 00076 Espoo, Finland; miina.a.rautiainen@aalto.fi
2 Faculty of Geo-Information Science and Earth Observ
7500 AE Enschede, The Netherlands; t.a.groen@utwe
3 Department of Electronics and Nanoengineering, Sch
P.O. Box 14100, 00076 Espoo, Finland
4 Center for Macroecology, Evolution and Climate (CM
University of Copenhagen, Universitetparken 15, DK
5 Department of Environment and Energy, Science and R
* Correspondence: sara.alibakhshi@aalto.fi; Tel.: +358-4

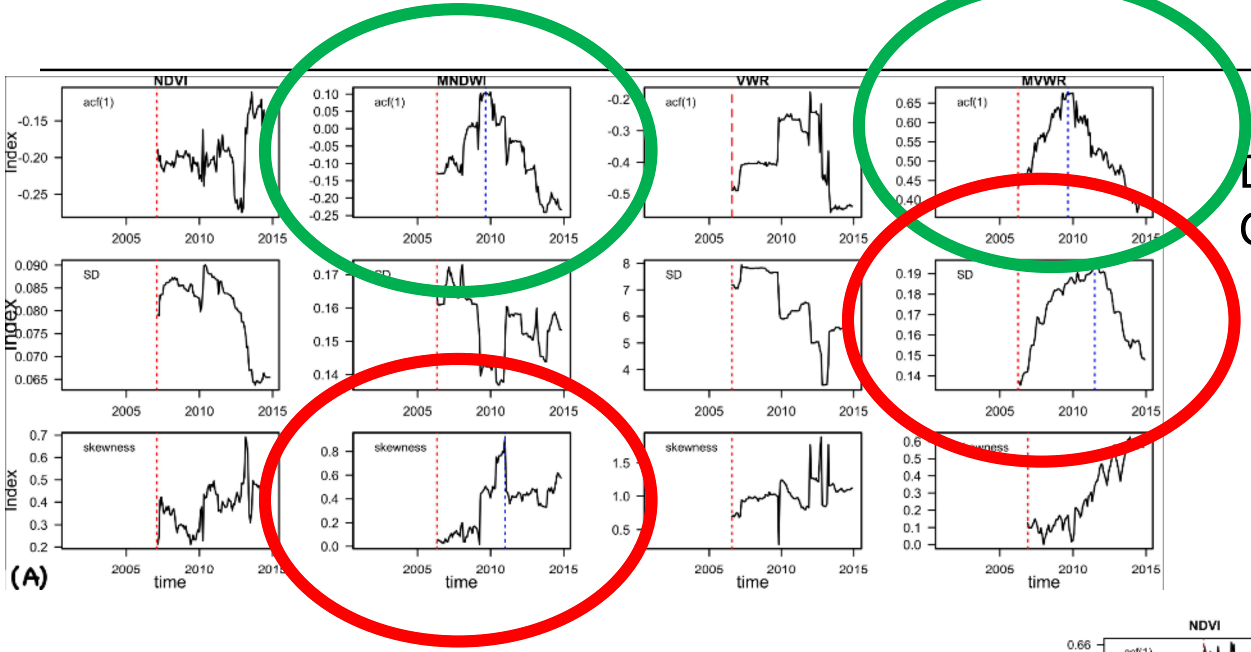
Academic Editors: Qiusheng Wu, Deepak R. Mishra and
Received: 30 September 2016; Accepted: 1 April 2017; Pu

Abstract: The response of an ecosystem to external d
Discontinuous and sometimes irreversible change



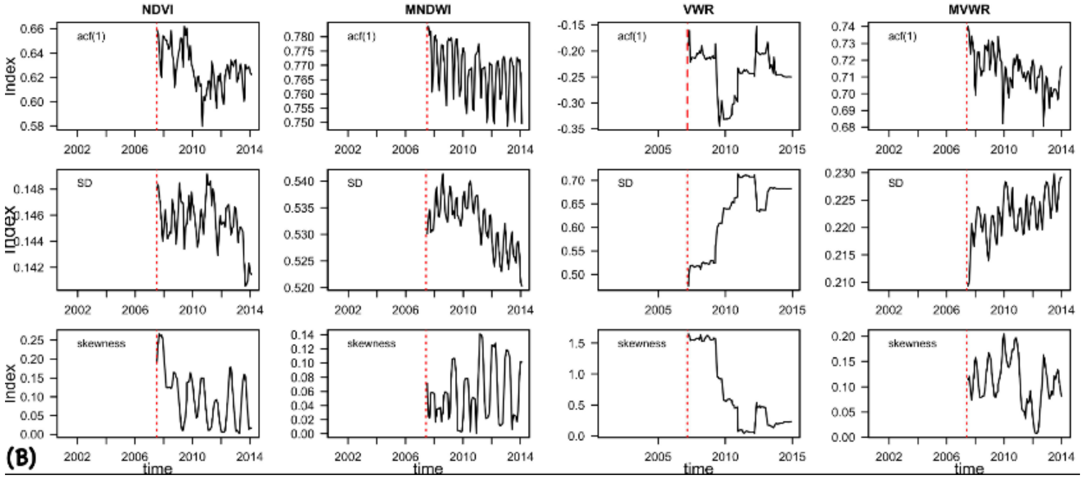


STABILITY DETECTION WITH RS



Dorge Sangi Wetland (Iran)
Converted into a vegetated state

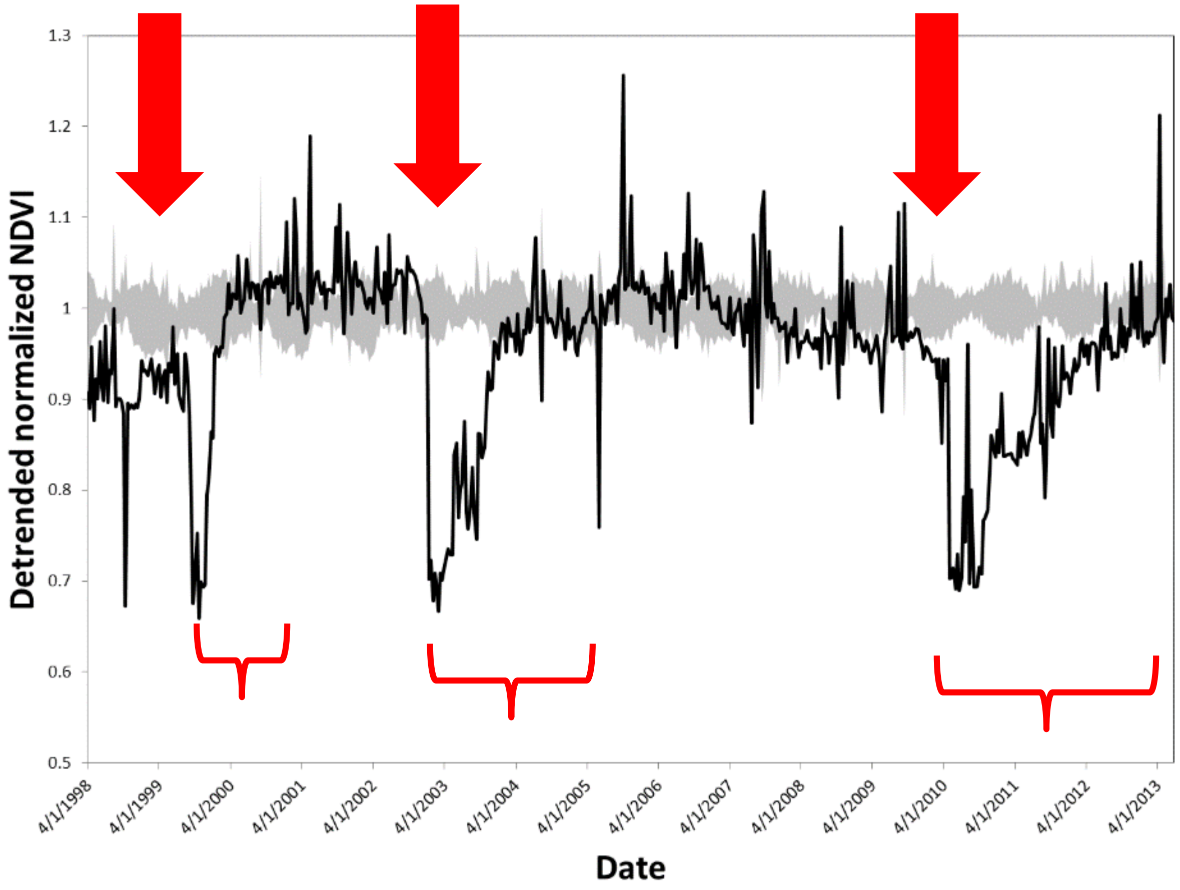
Arpi Wetland (Armenia)
Remained a wetland

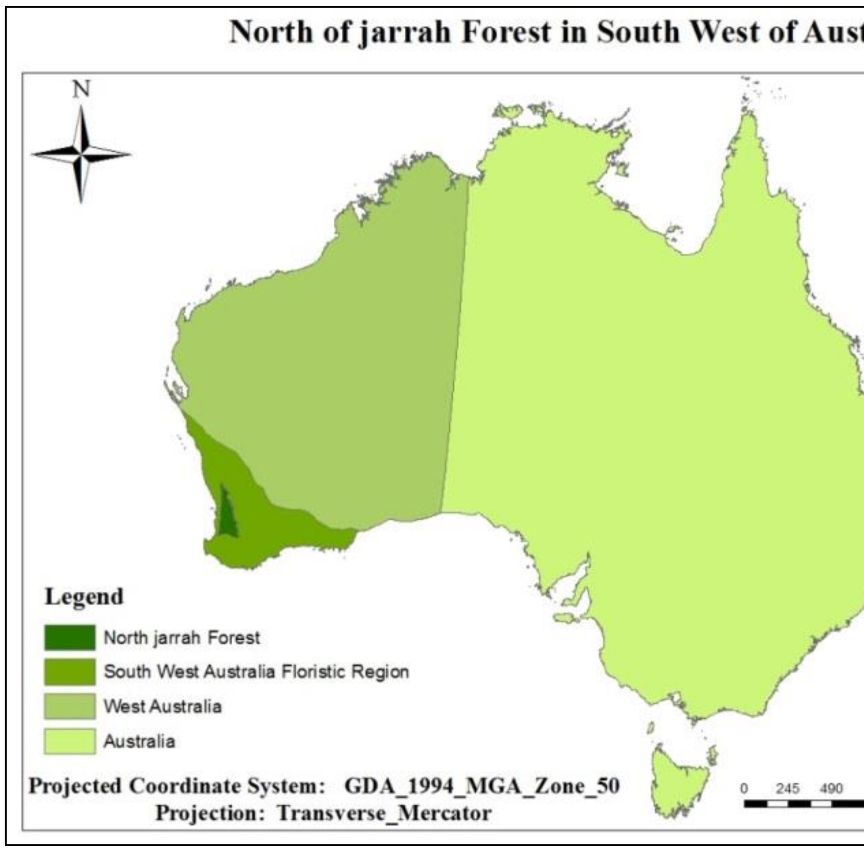


MEDITERRANEAN SYSTEMS?

Pictures:
Matusick et al.
(2013)

RECOVERY AFTER FIRES

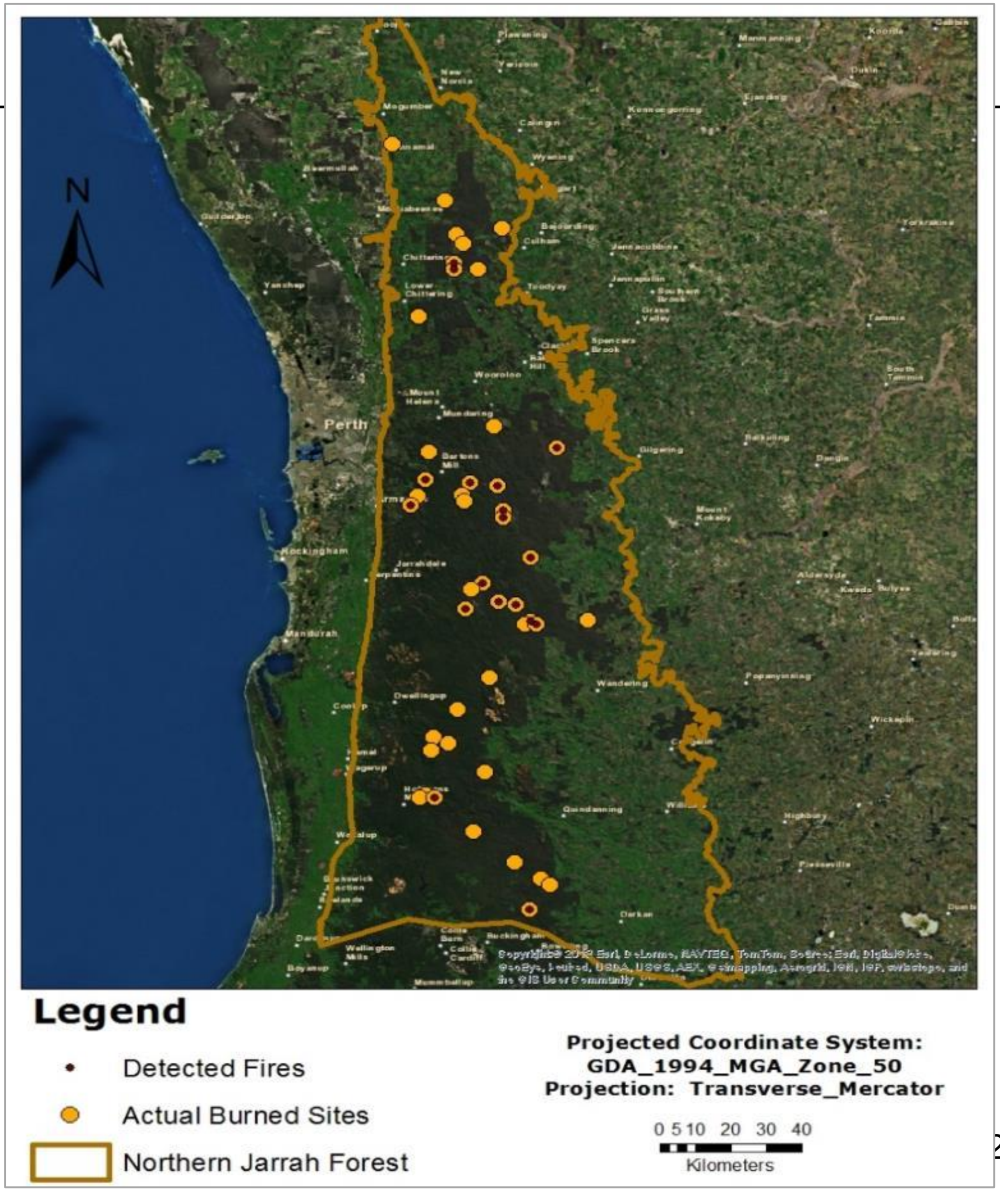




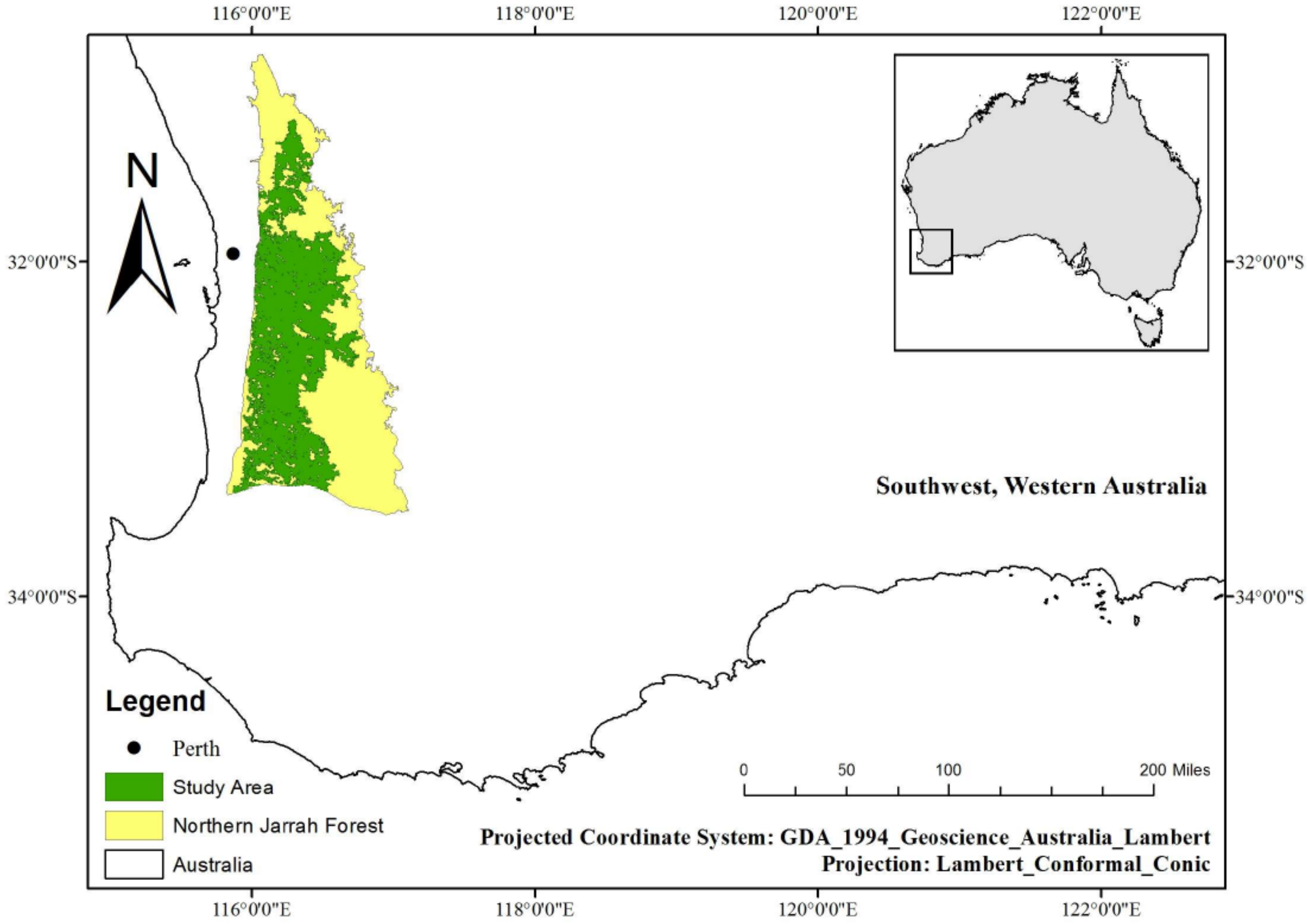
RECOVERY AFTER FIRES

Summary	
R_2	0.70
P_value	0.0002118

$RT \sim \text{Fire Interval} - P_{\text{grow seas.}} + P_{\text{fire month}} + P_{\text{recov period}}$



STABILITY INDICATORS FROM CONTINUOUS TS?



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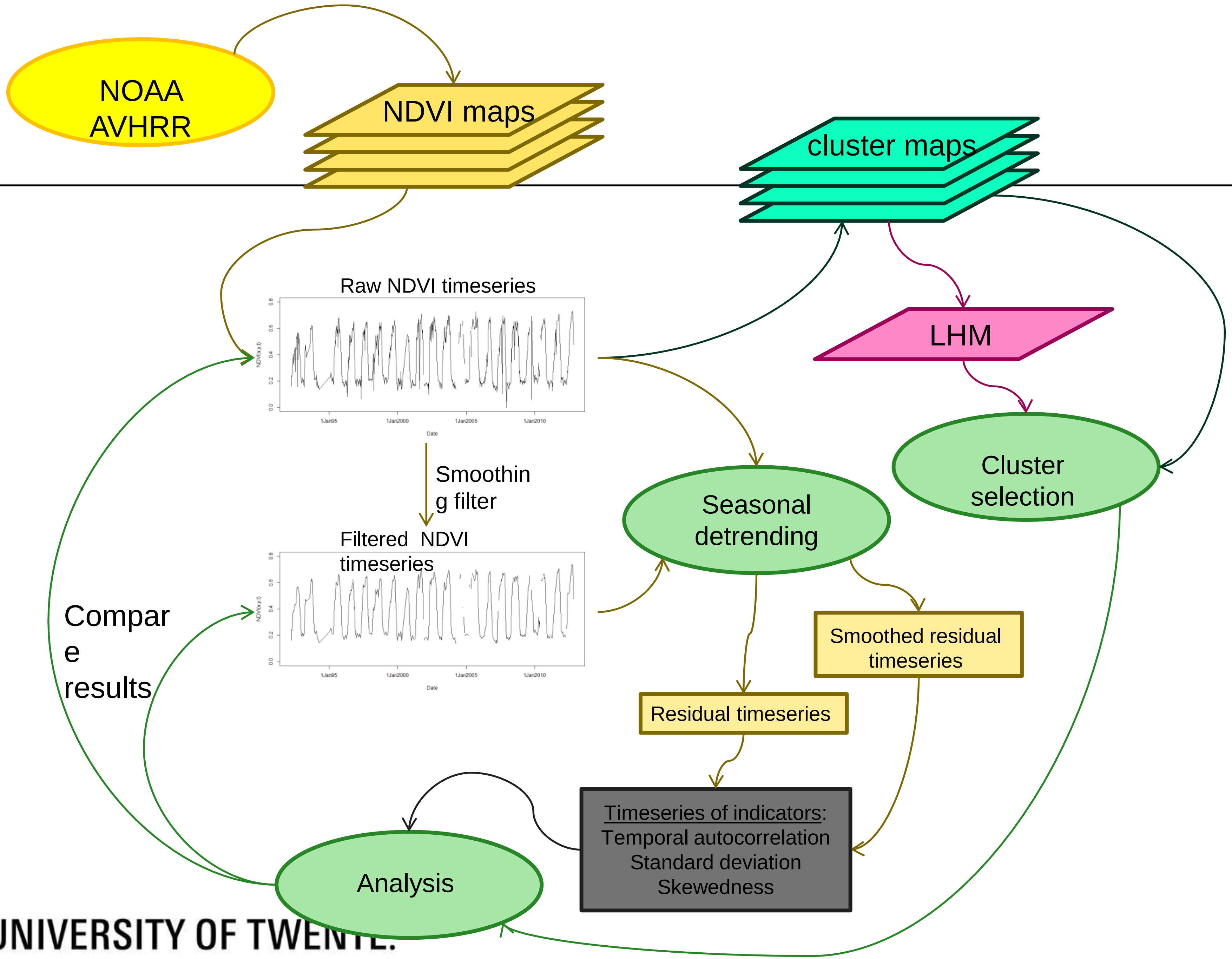
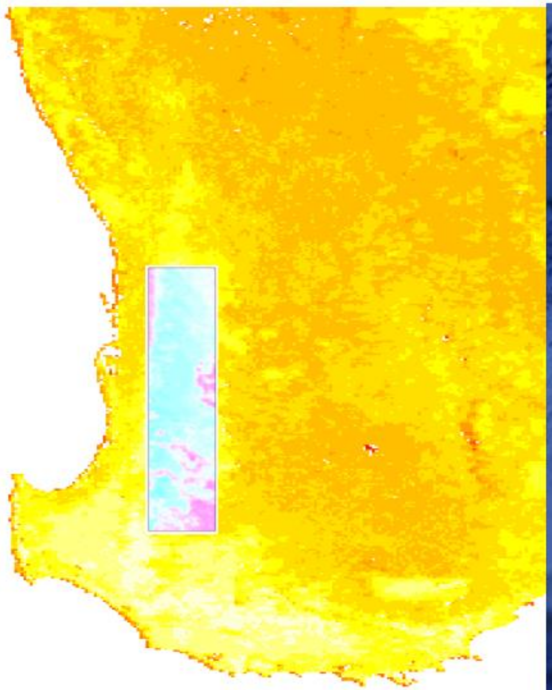
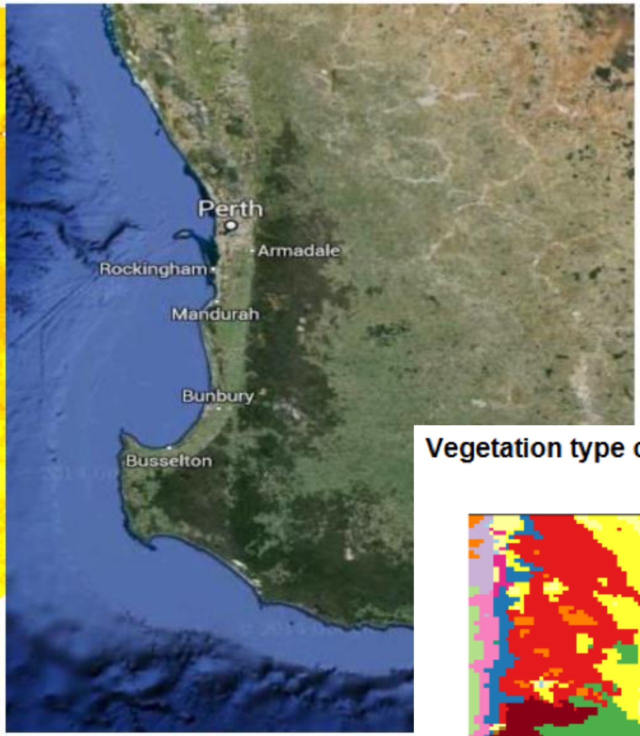
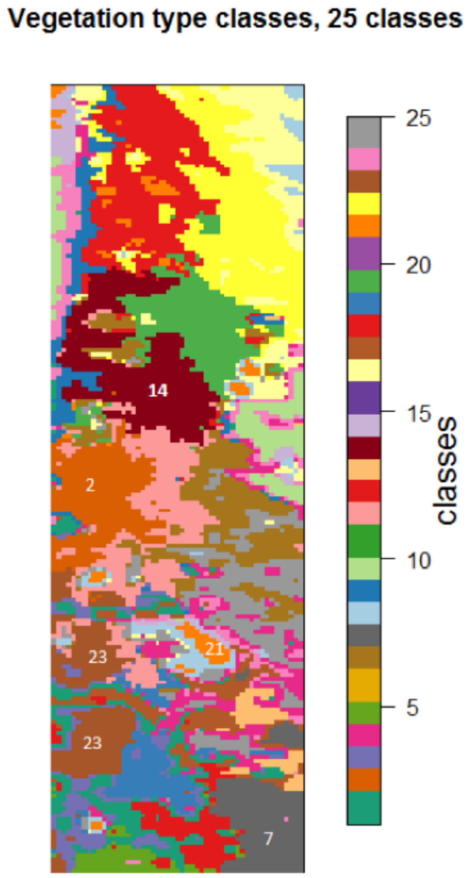
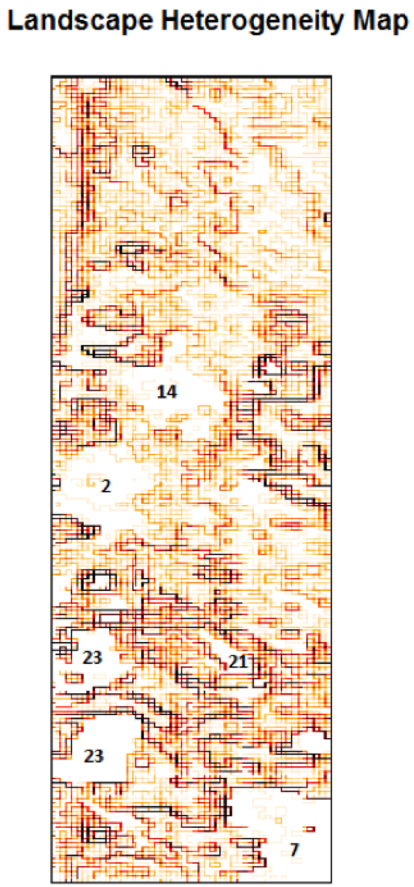

NOAA AVHRR
NDVI maps
cluster maps
LHM
Raw NDVI timeseries
Smoothing filter
Filtered NDVI timeseries
Seasonal detrending
Cluster selection
Smoothed residual timeseries
Residual timeseries
Compare results
Timeseries of indicators:
Temporal autocorrelation
Standard deviation
Skewedness
Analysis









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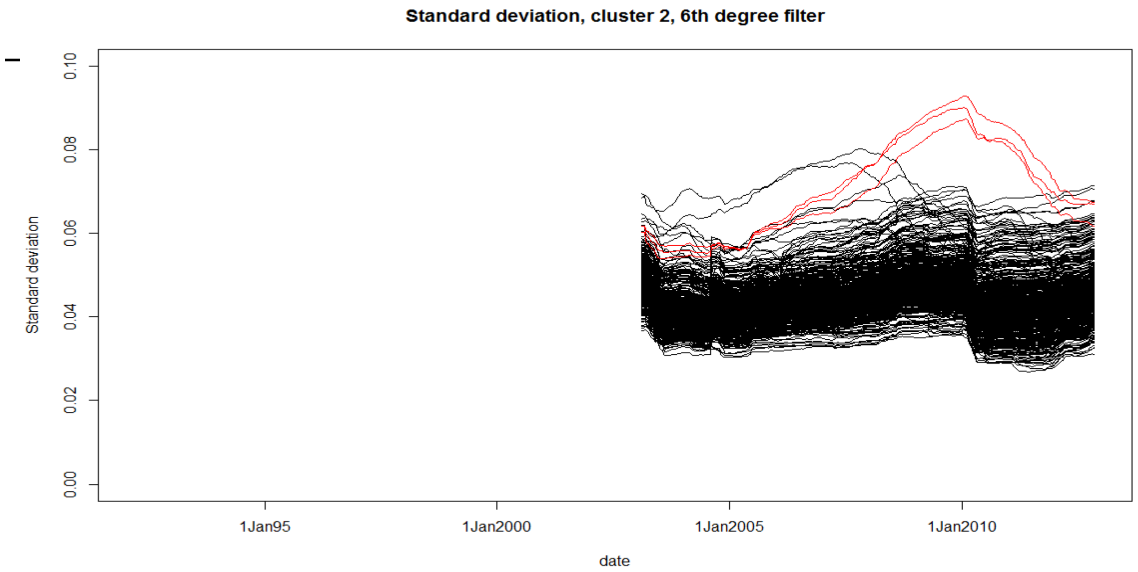
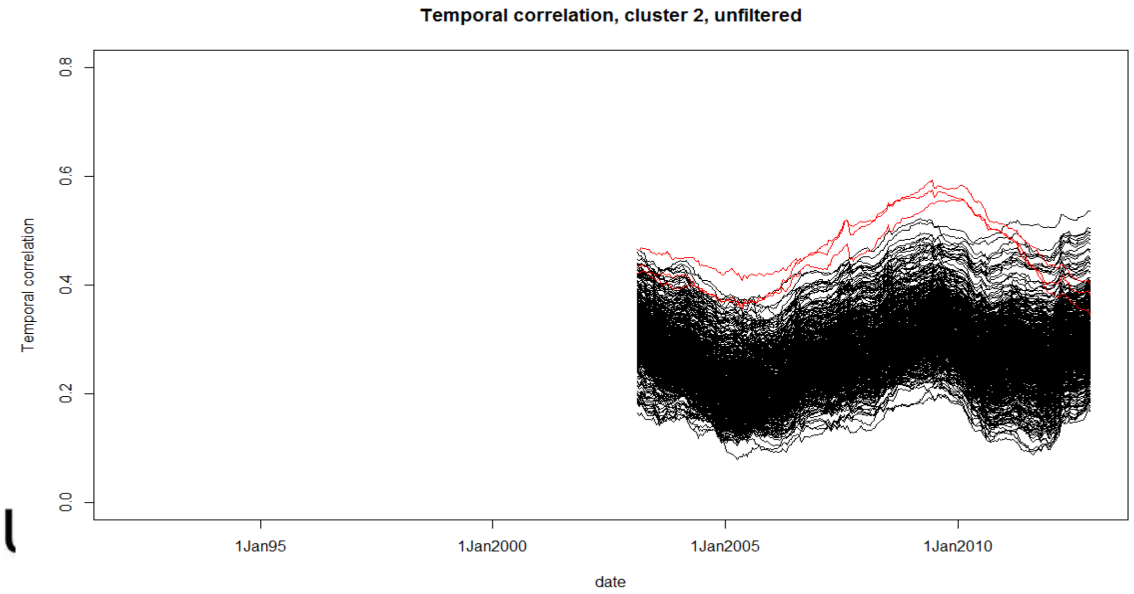
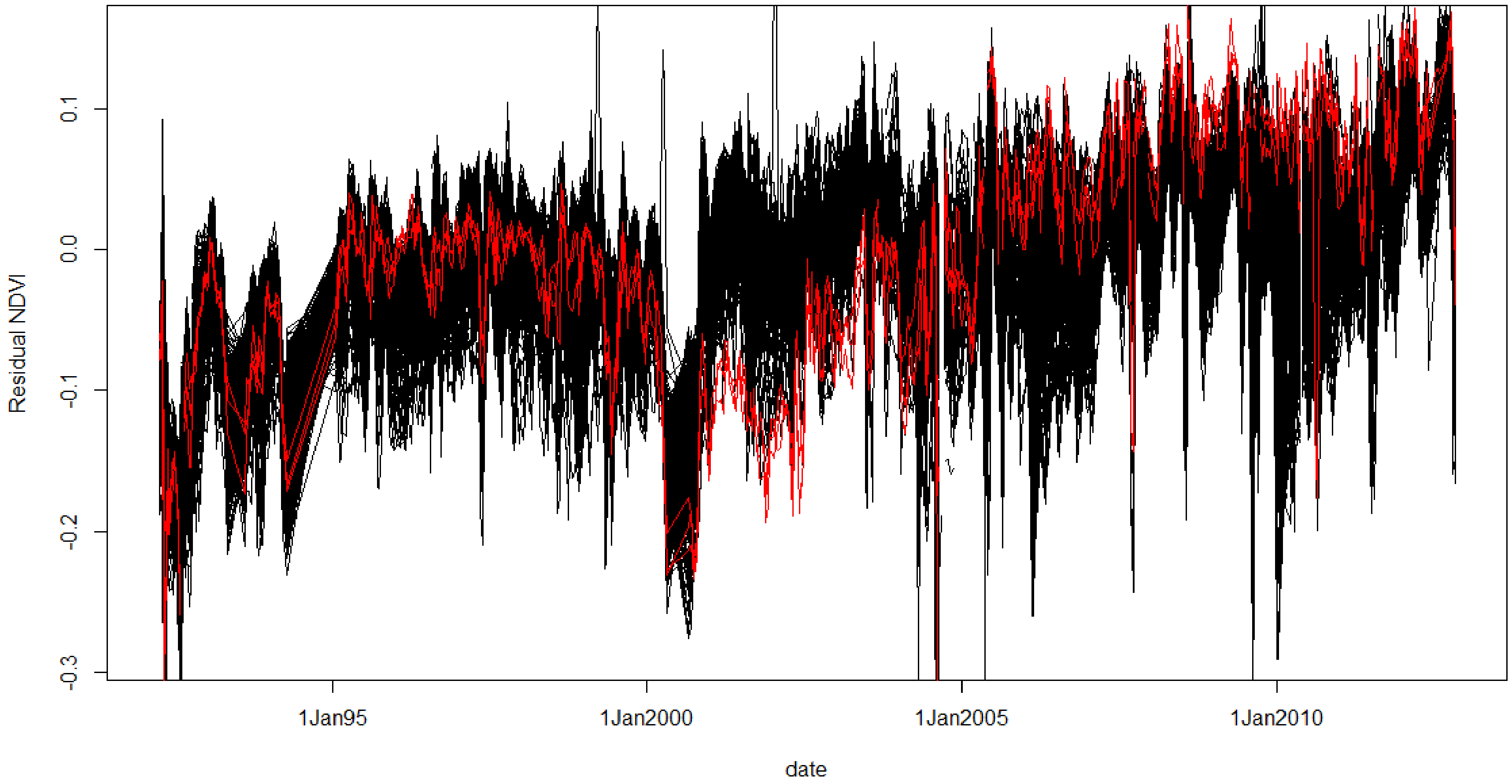
TS ANALYSIS WITHIN HOMOGENEOUS CLUSTERS



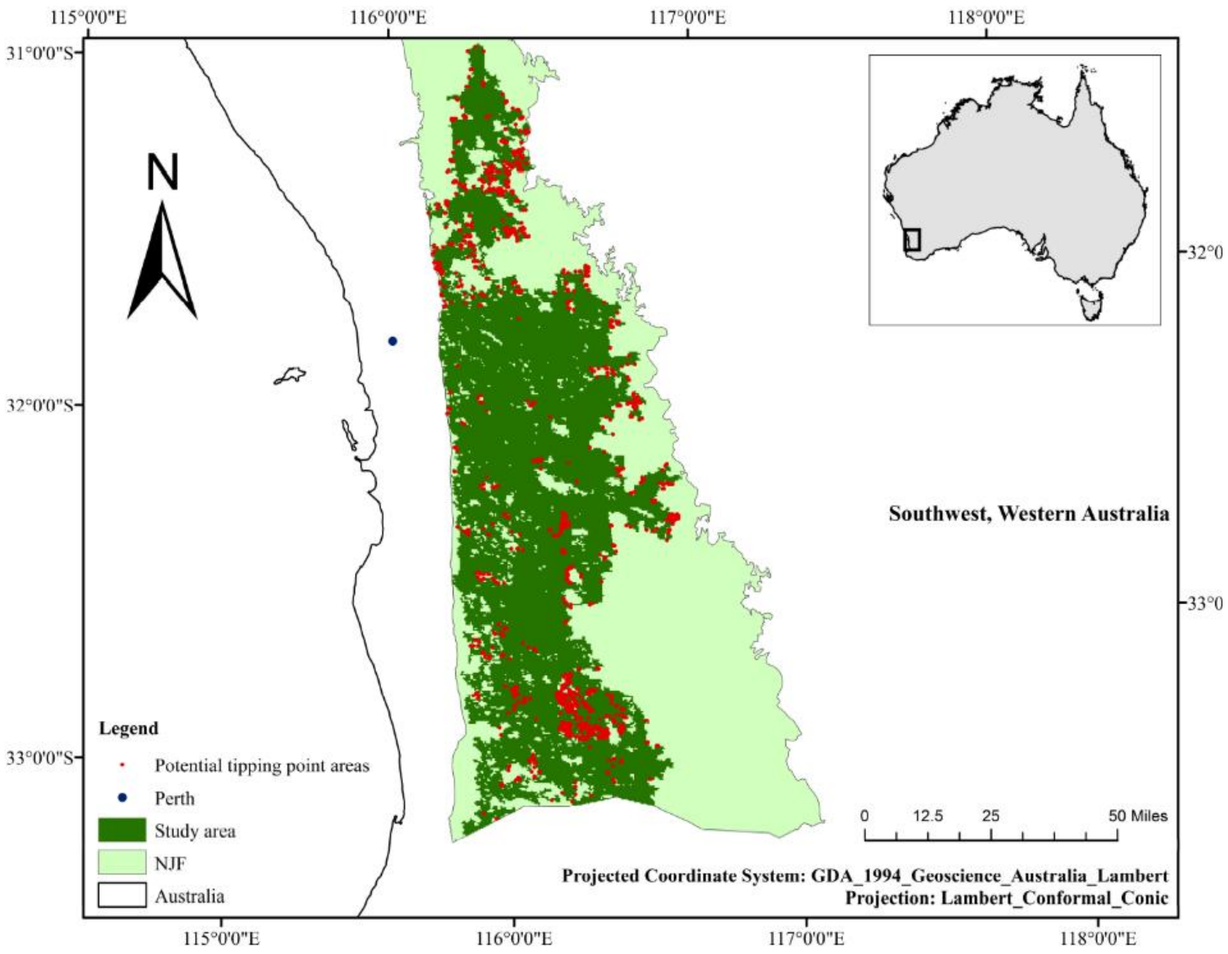


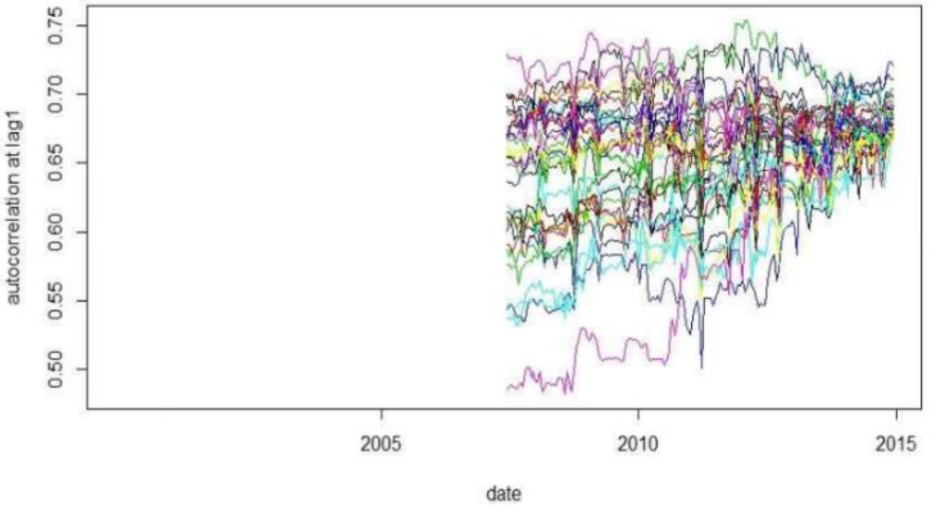
- Standard deviation and temporal autocorrelation robust against filtering
- Skewedness very sensitive to filtering and extreme values → omitted

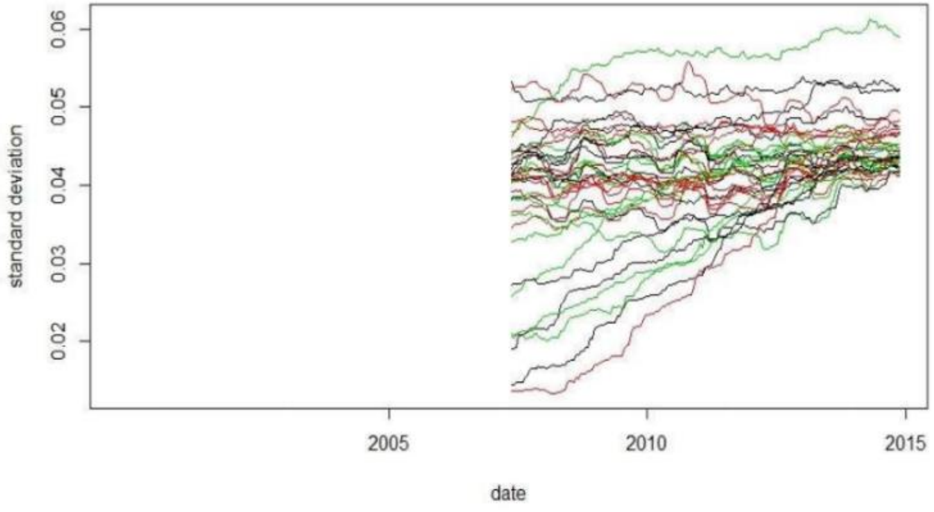
TS ANALYSIS WITHIN HOMOGENEOUS CLUSTERS



TS ANALYSIS ACROSS ENTIRE SYSTEM





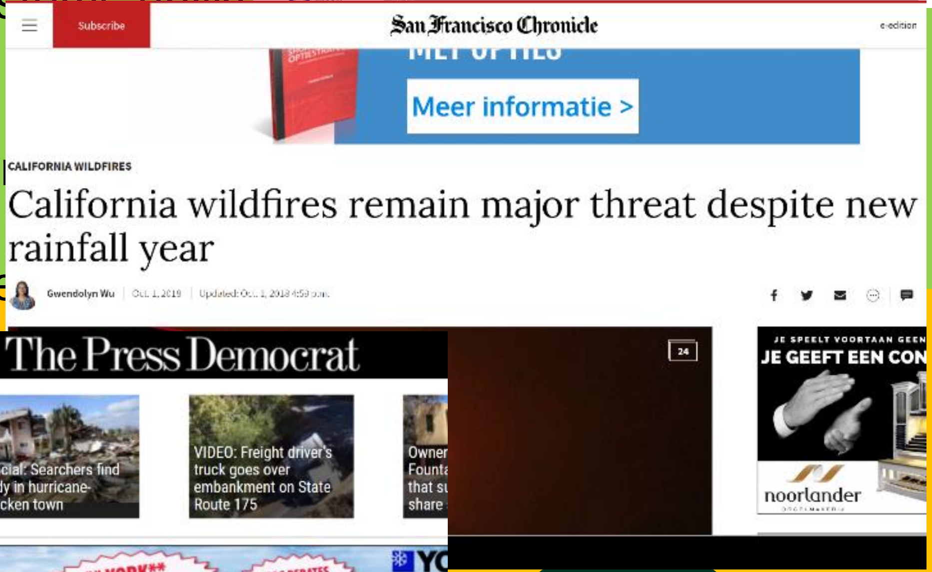


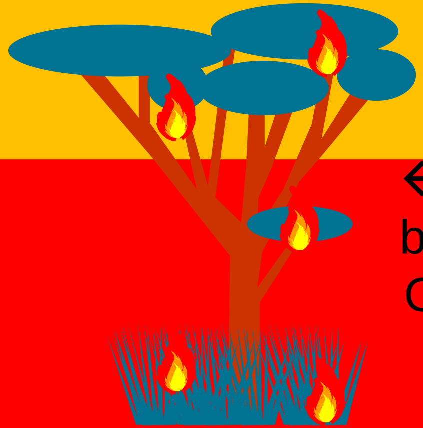
FIRE AS THE TIPPING EVENT

Sufficiently moist Ecosystems unlik

Ecosystems that experie
to burn

- mainly grasses and he

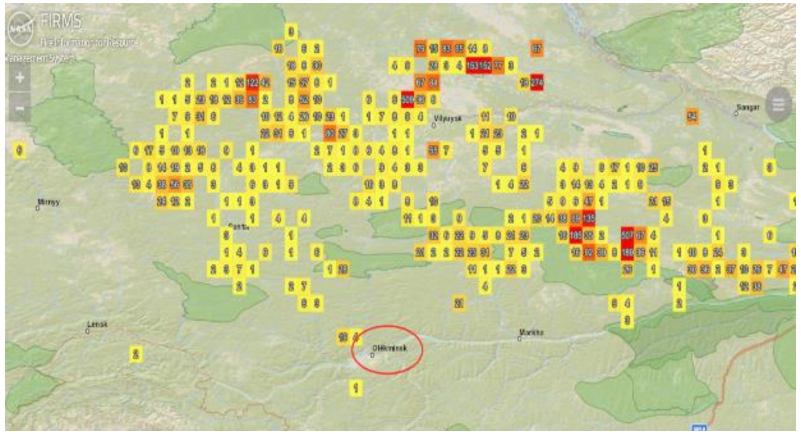


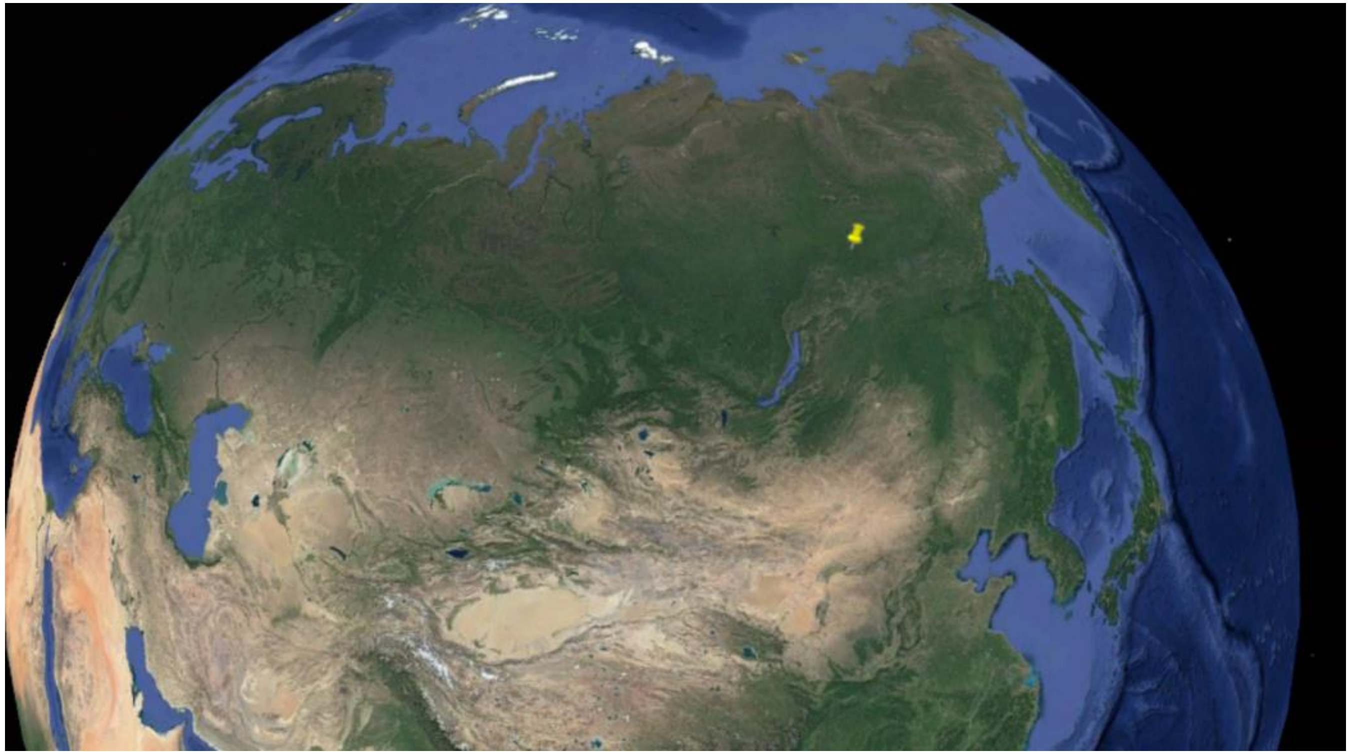


←If c
beco
Or bi

FIRE AS THE TIPPING EVENT

- See fire as the manifestation of a “tipping event”
- Cluster based on detrended EWS signals
- Test how fire events associate with these types of clusters





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WRAP UP

- RS based EWS indicators work (sometimes)
- Top down approach gives supporting evidence (but is circumstantial)
- Need Bottom up cases (When you know about collapsed (or collapsing) ecosystems -> **let me know!**)
  - Which RS product to use
  - Determine at which threshold EWS indicate tipping point

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THANK YOU FOR LISTENING