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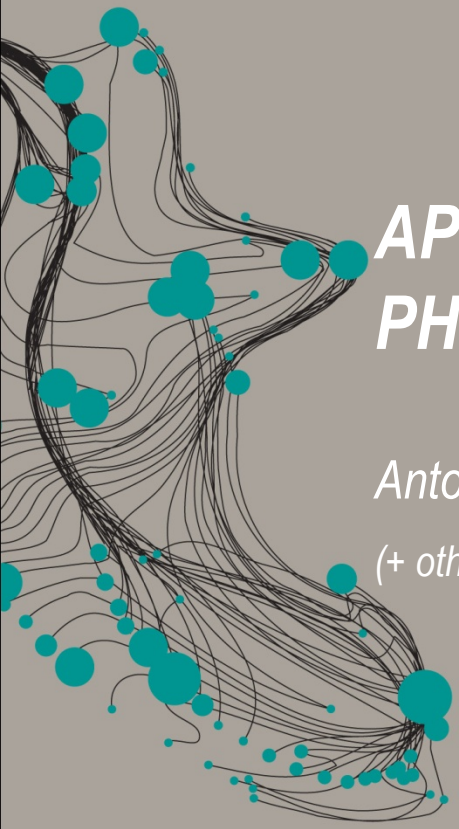
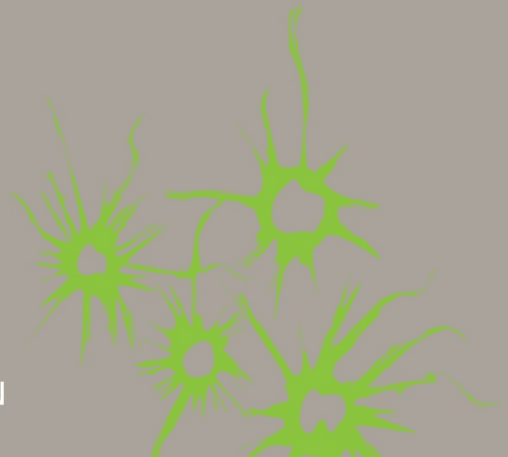
APPLICATIONS OF SATELLITE-DERIVED PHENOLOGY

Anton Vrieling

(+ others)





ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

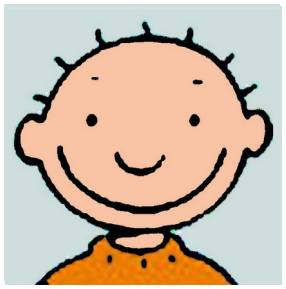
SHORT OVERVIEW

- Use of phenology information for a drought insurance programme
- Cover crops after maize (Netherlands)

DROUGHT AND EAST AFRICAN PASTORALISTS

- Horn of Africa:
  - > 20 million pastoralists that depend on livestock
  - exports of livestock & livestock products > $1billion
  - drought is main cause of livestock loss → source of poverty
  - standard responses (food/cash aid) are slow, costly, and insufficient
- Insurance as option?

HOW DOES INSURANCE WORK?



WHAT IS INSURANCE?

- Risk management with idea to protect against uncertain financial losses
  - contract (insurance policy) between insurer and insured
  - conditions and circumstances under which the insured will be compensated
  - insured pays premium
  - insurer pays indemnity when a loss is covered in the contract
- Insurance versus gambling
  - same: you bet money now because you will likely get a larger payout in the future.
  - different: gamblers seek risk in an attempt to get more money; when you buy insurance, you seek to reduce risk so you don't lose more money.

INSURING ANIMALS?

- Remote areas
  - No cost-effective options to check losses
- Alternative: index insurance
  - base premium and payout on a biophysical index
  - correlates to losses
  - forage scarcity index

⇓

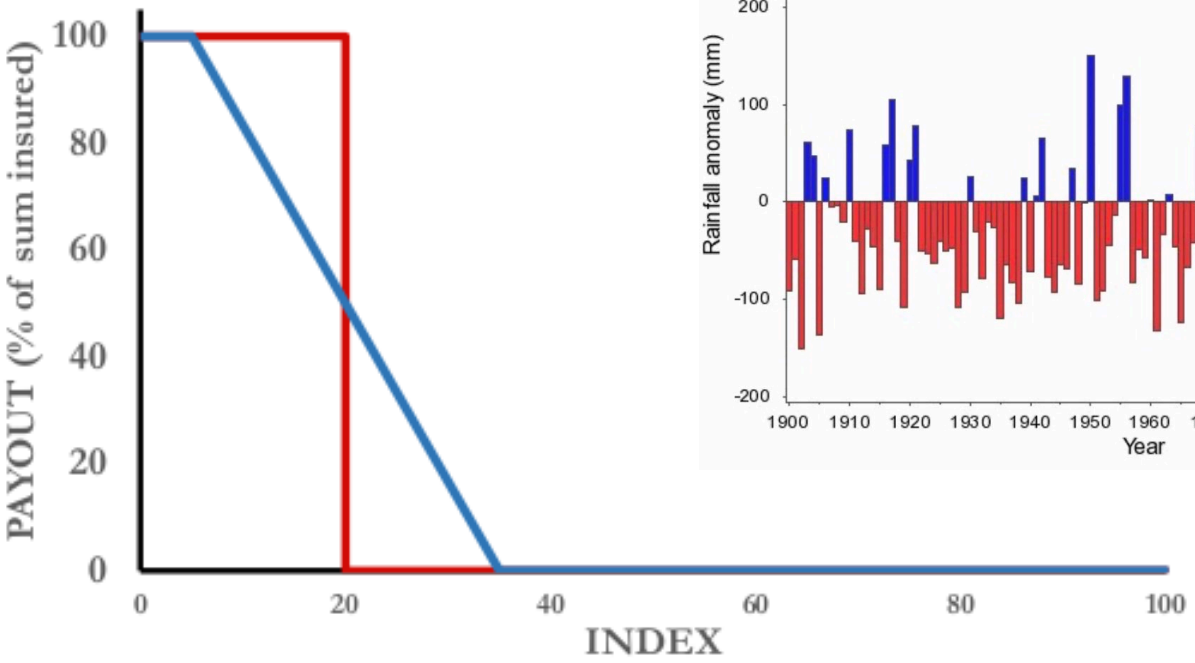
from NDVI time series

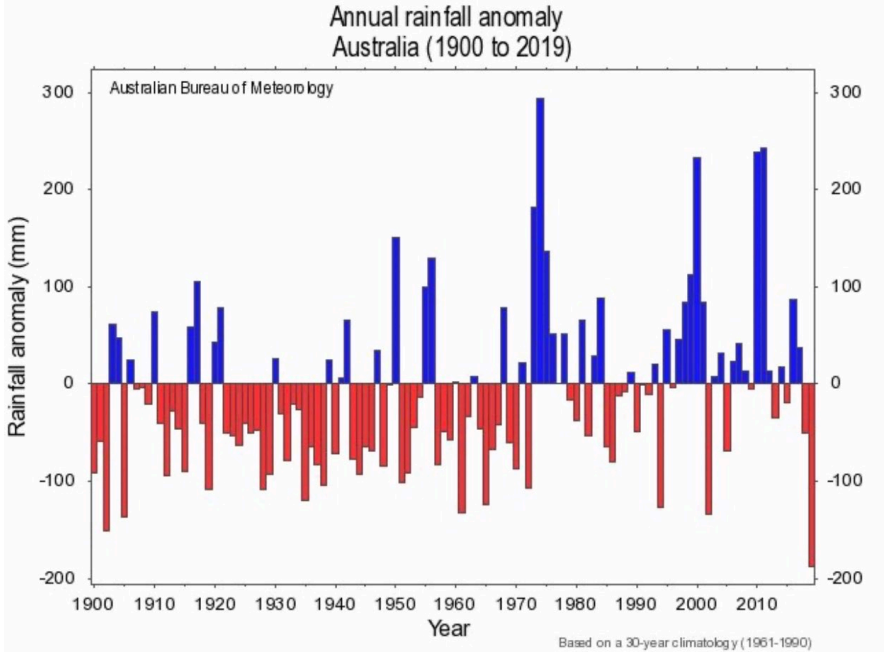
⇓

does a season have below-normal forage within the insured area to warrant an indemnity payment?

WATCH VIDEO ?

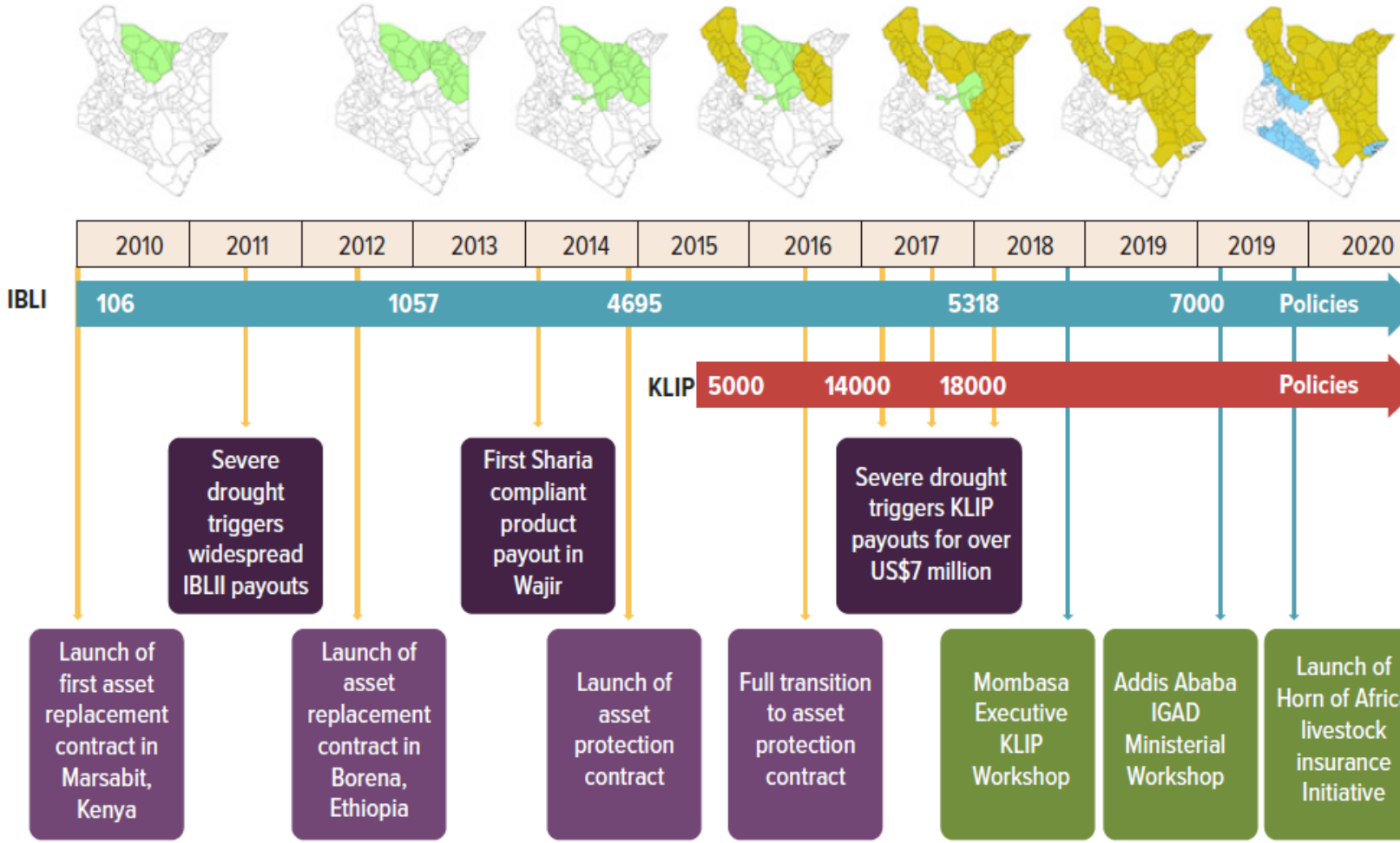
HOW INDEX INSURANCE WORKS





worsening seasonal forage condition

IBLI & EXPANSION



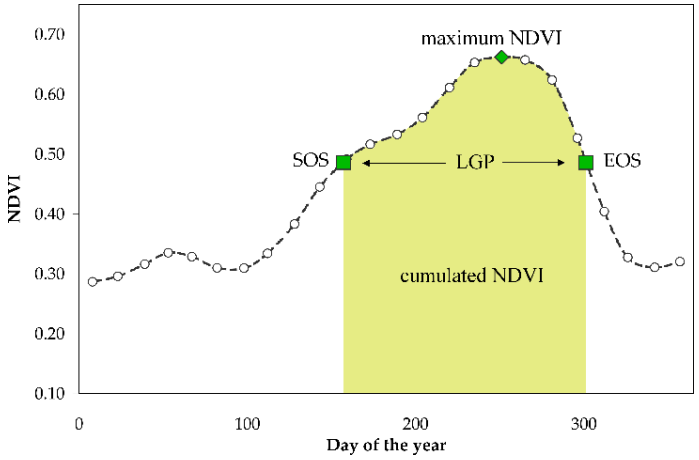
Note: The map illustrates expansion of coverage with IBLI (green), IBLI and KLIP combined (yellow), and planned KLIP expansion (light blue) in Kenya.
Source: Authors' elaboration

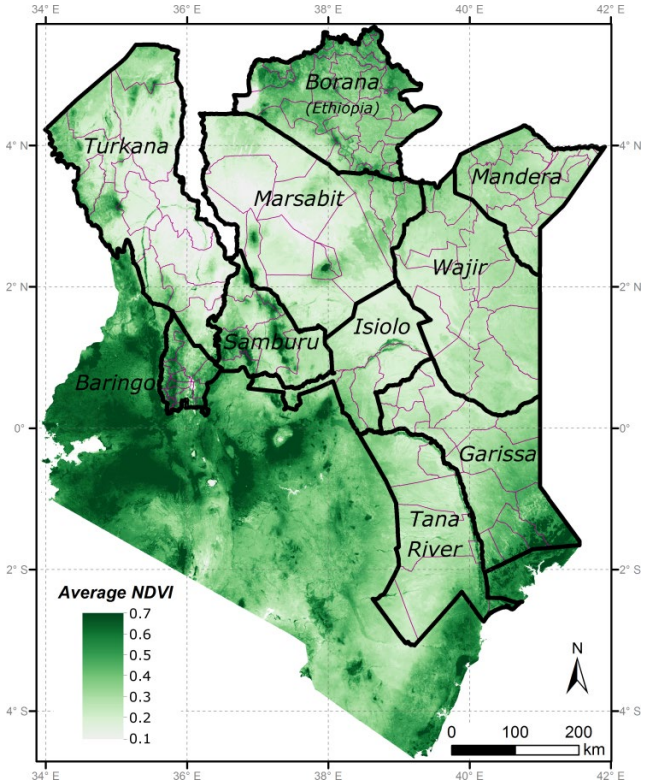
INDEX REQUIREMENTS

1. strong correlation with what is insured
2. independently verifiable, i.e. based on well-described data sources and processing methods
3. reliable delivery into future + available in near real-time
4. available for sufficiently long period to properly represent climatic variability → payout probability and pricing
5. information gathering at limited cost for insurer

INDEX SELECTION

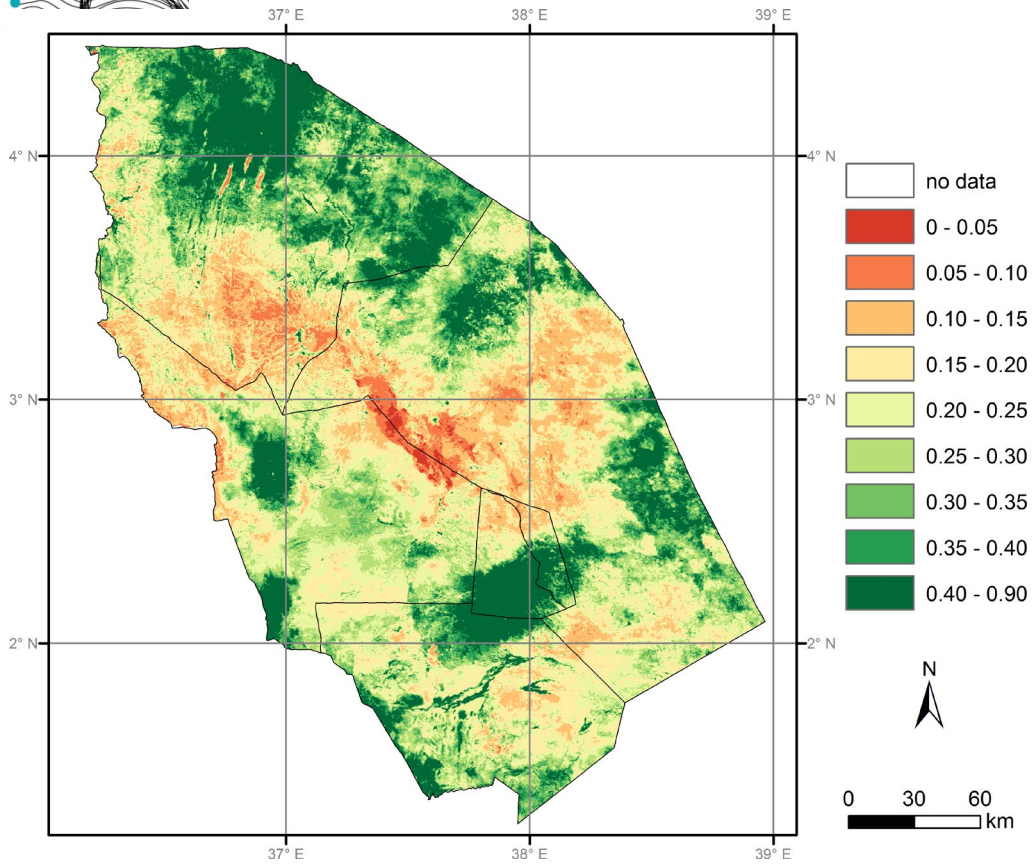
- Drought occurrence can be estimated in many ways
  - RFE, soil moisture, …
- IBLI uses a forage scarcity index
  - measure of area-average seasonal forage availability
    - relative to historic availability
  - eMODIS NDVI as input



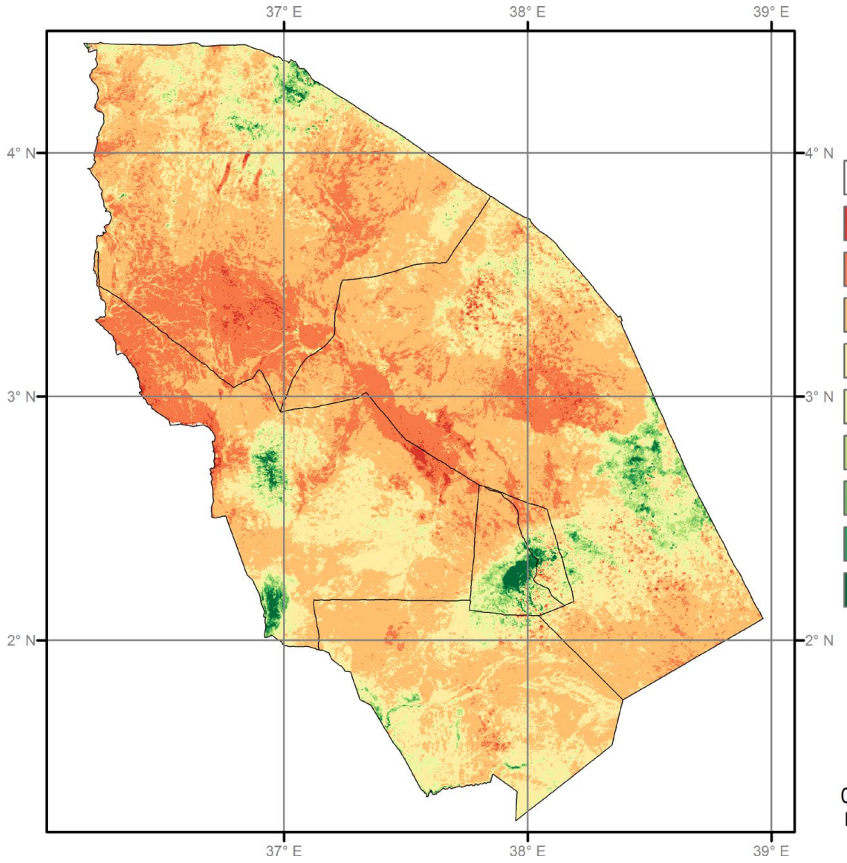


ANOMALIES: COMPARE NDVI IN TIME

May 2010



May 2011

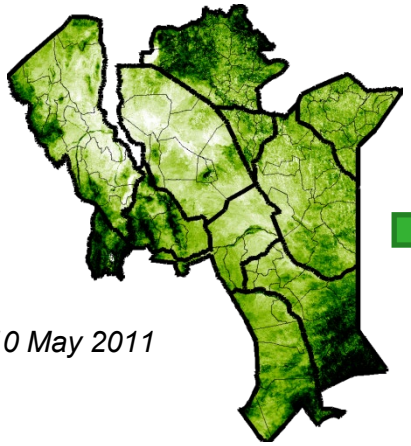


Vrieling et al. 2016. Early assessment of seasonal forage availability for mitigating the impact of drought on East African pastoralists. *Remote Sensing of Environment* 174: 44-55

FORAGE SCARCITY INDEX

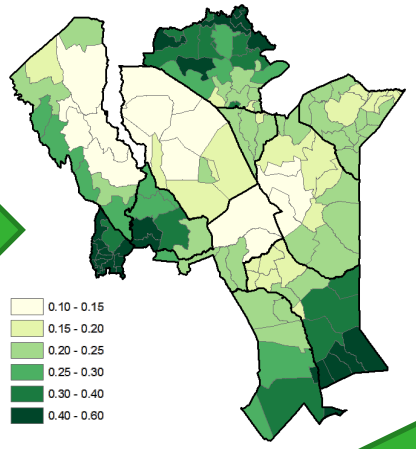
1. ecology
2. when pay indemnity?

NDVI image (10 day)

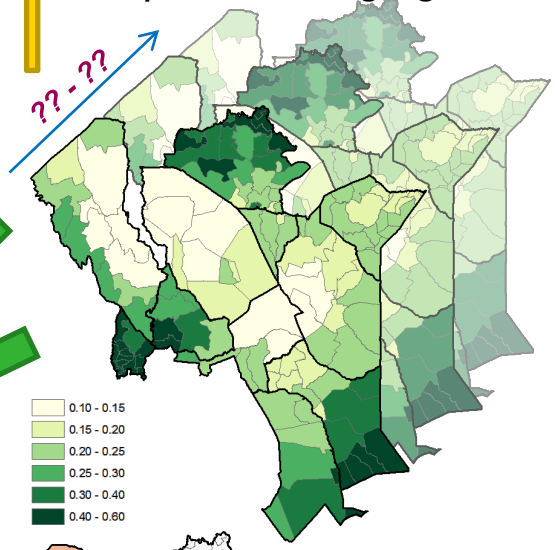


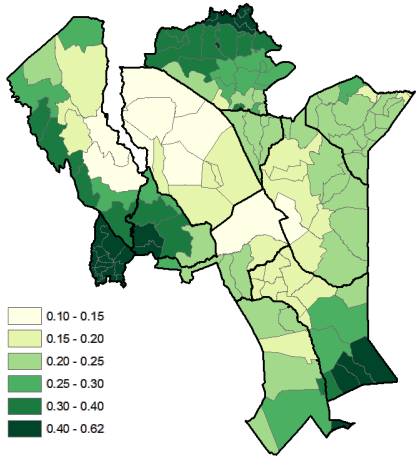
1-10 May 2011

NDVI aggregated



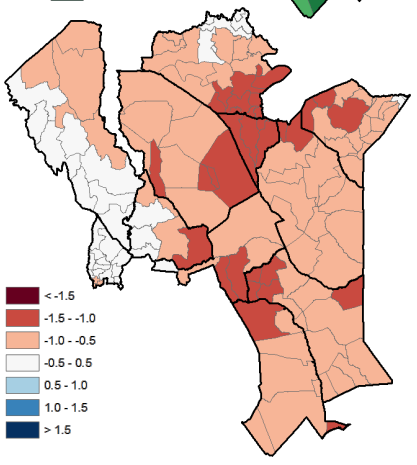
Temporal averaging





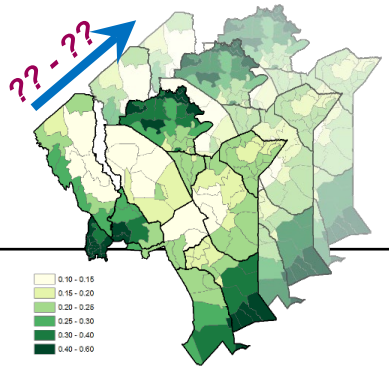
Seasonal average NDVI

Z-scoring (compared to 15 years) to get seasonal index

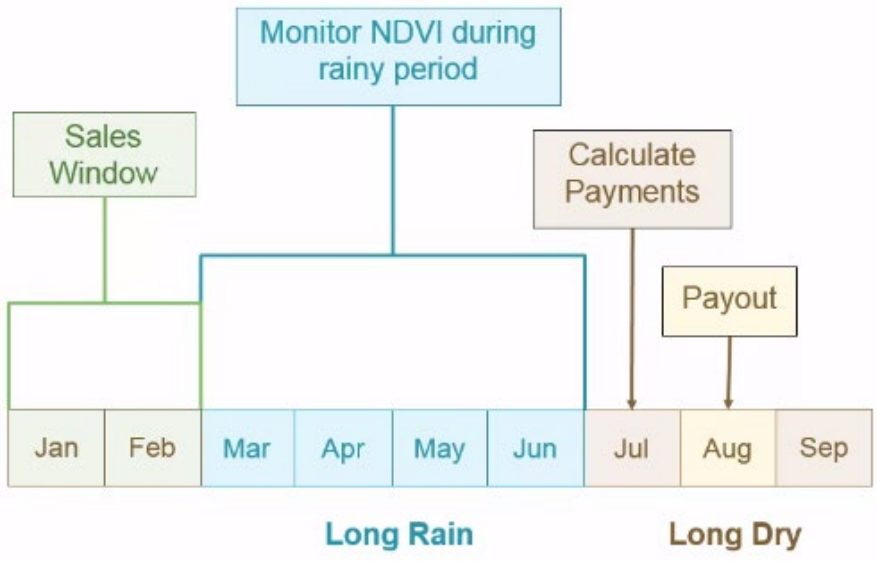


Z-scoring to get seasonal index

TIMING ISSUES: IMPLICATIONS

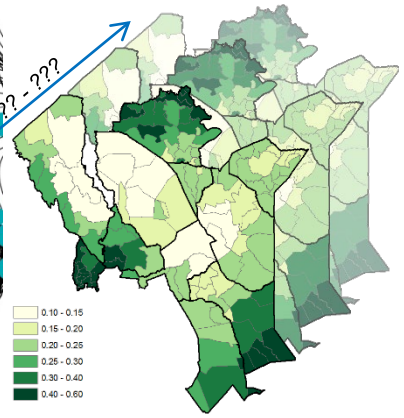


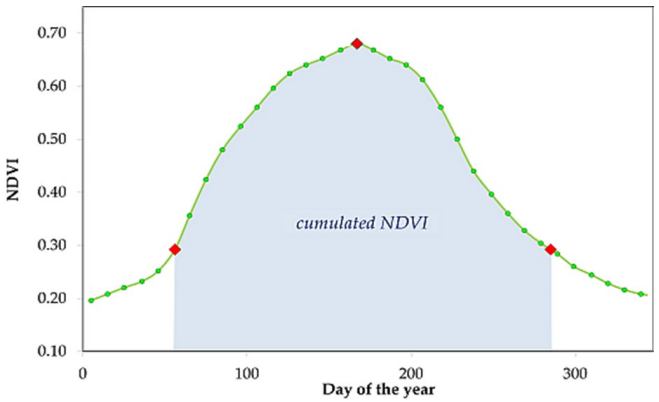
- Optimal link to forage availability
- Also determines: 1) when to sell, 2) when can payouts be made ?

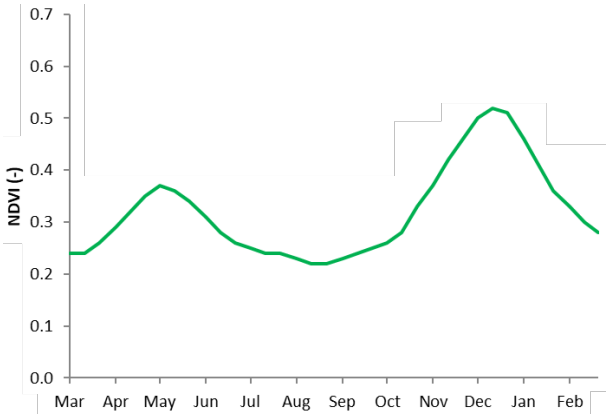


- Insure to buy new animals? *asset replacement*
- Or cost to keep animals alive? *asset protection*

HOW TO GET A PROPER INDEX OF PRODUCTIVITY?







- Before:
  - LRLD: March – September
  - SRSD: October – February
- What we did:
  - Assess per unit start/end of season
  - Phenological analysis
  - Interannual cumNDVI variability → predict?

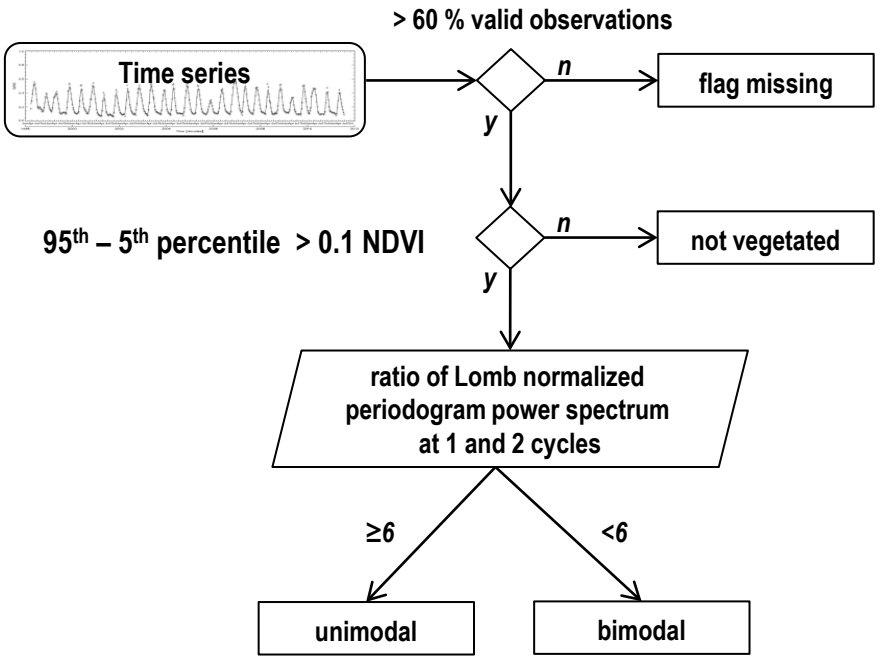
THE PROBLEM WITH LRLD/SRSD DEFINITIONS?

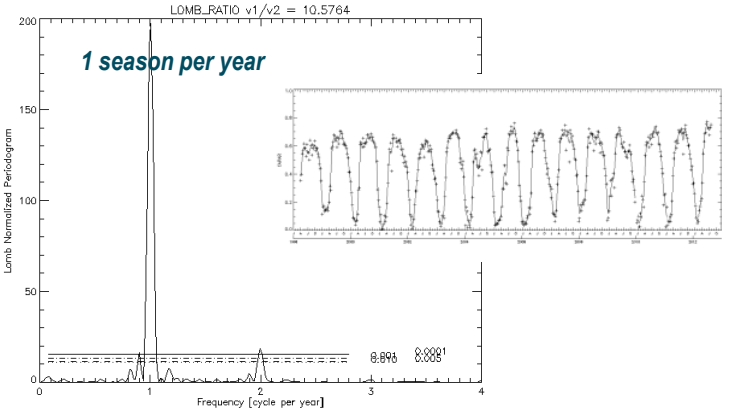
- Index → overall forage conditions for season
- NDVI describes *green vegetation* ≠ all forage
- But forage in dry season has been green!
  - → focus on green biomass build-up only
  - → Phenological analysis to determine start- and end-of-season

*Adapted version as described in: Meroni M, MM Verstraete, F Rembold, F Urbano, and F Kayitakire. 2014. A phenology-based method to derive biomass production anomaly for food security monitoring in the Horn of Africa. International Journal of Remote Sensing, 35: 2472-2492.

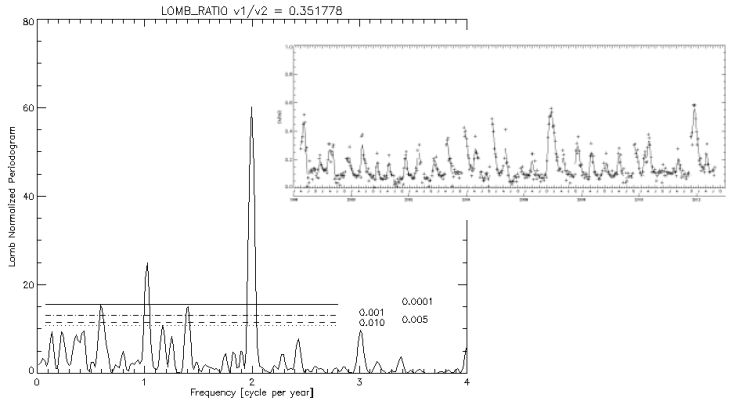
PHENOLOGY RETRIEVAL FROM EMODIS (2001-2015)

- Step 1: screening and retrieval of number of seasons per year





2 seasons per year



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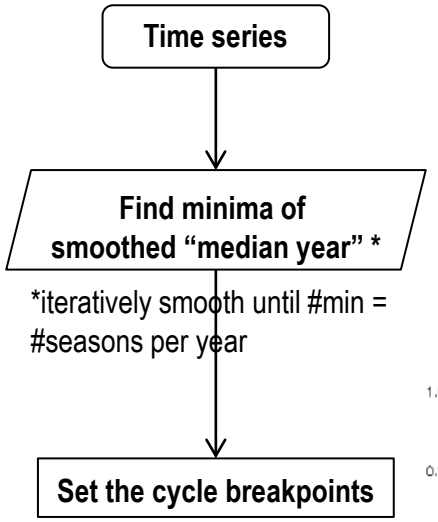
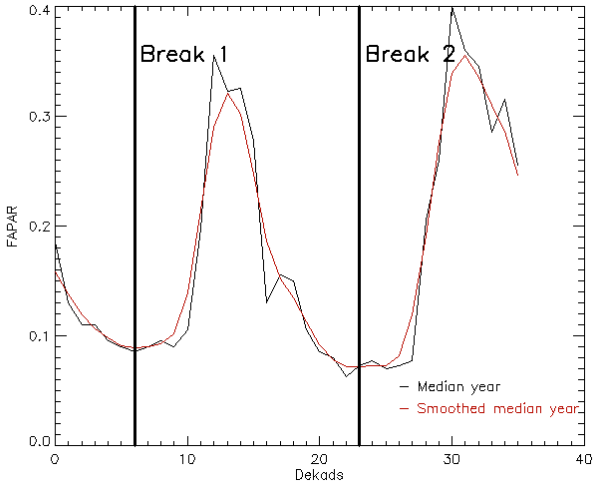
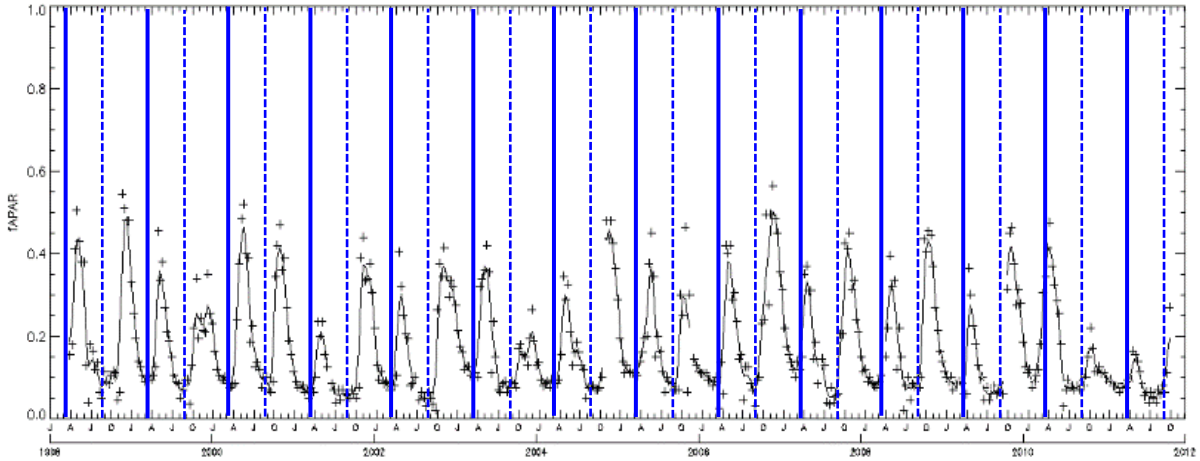
PHENOLOGY RETRIEVAL

- Step 2: retrieval of pixel “climatology”: set temporal breakpoints that separate the periodic climatic cycles in the time-series

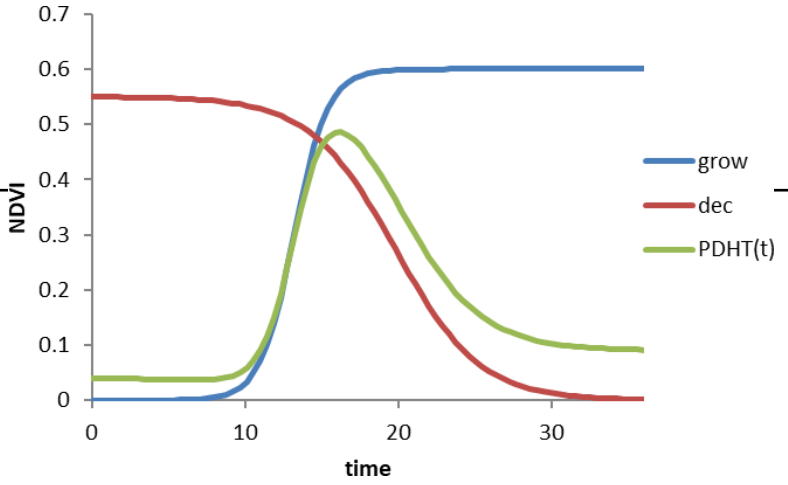




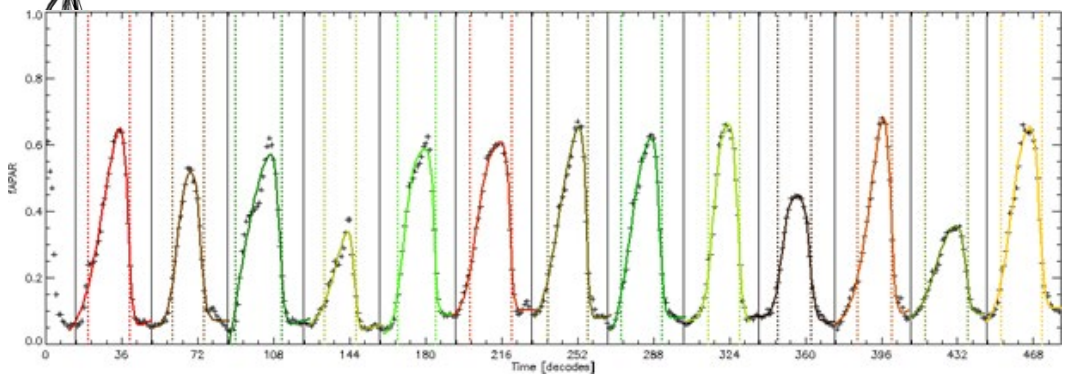


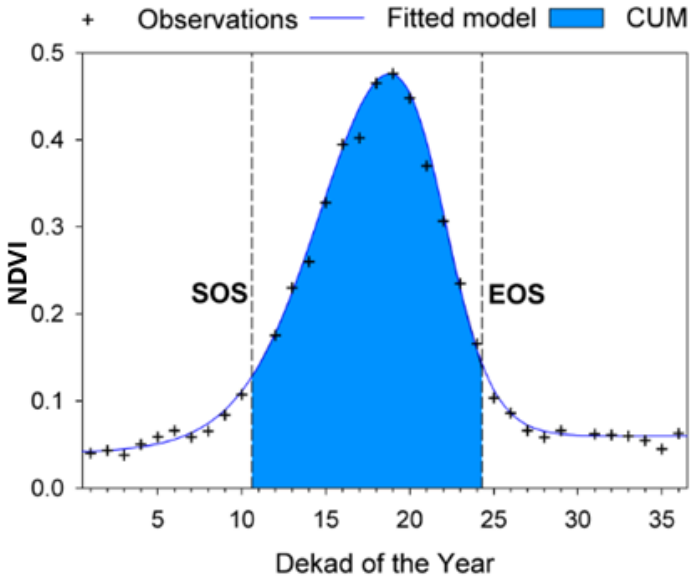
PHENOLOGY RETRIEVAL

- Step 3: model fitting (per season)
  - Parametric Double Hyperbolic Tangent Model to represent typical seasonal signal (7 parameters)
  - *Note: equivalent to double logistic model*



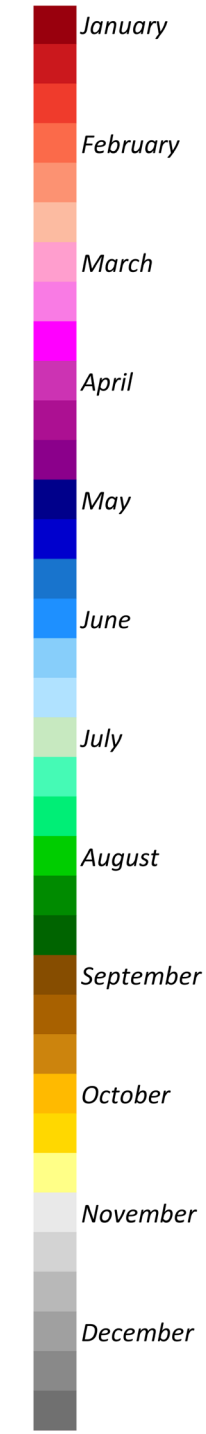
$$PDHT(t) = a_0 + \frac{1}{2}a_1\{tanh[(t-a_2)a_3]+1\} + \frac{1}{2}a_4\{tanh[(t-a_5)a_6]+1\} - a_4$$

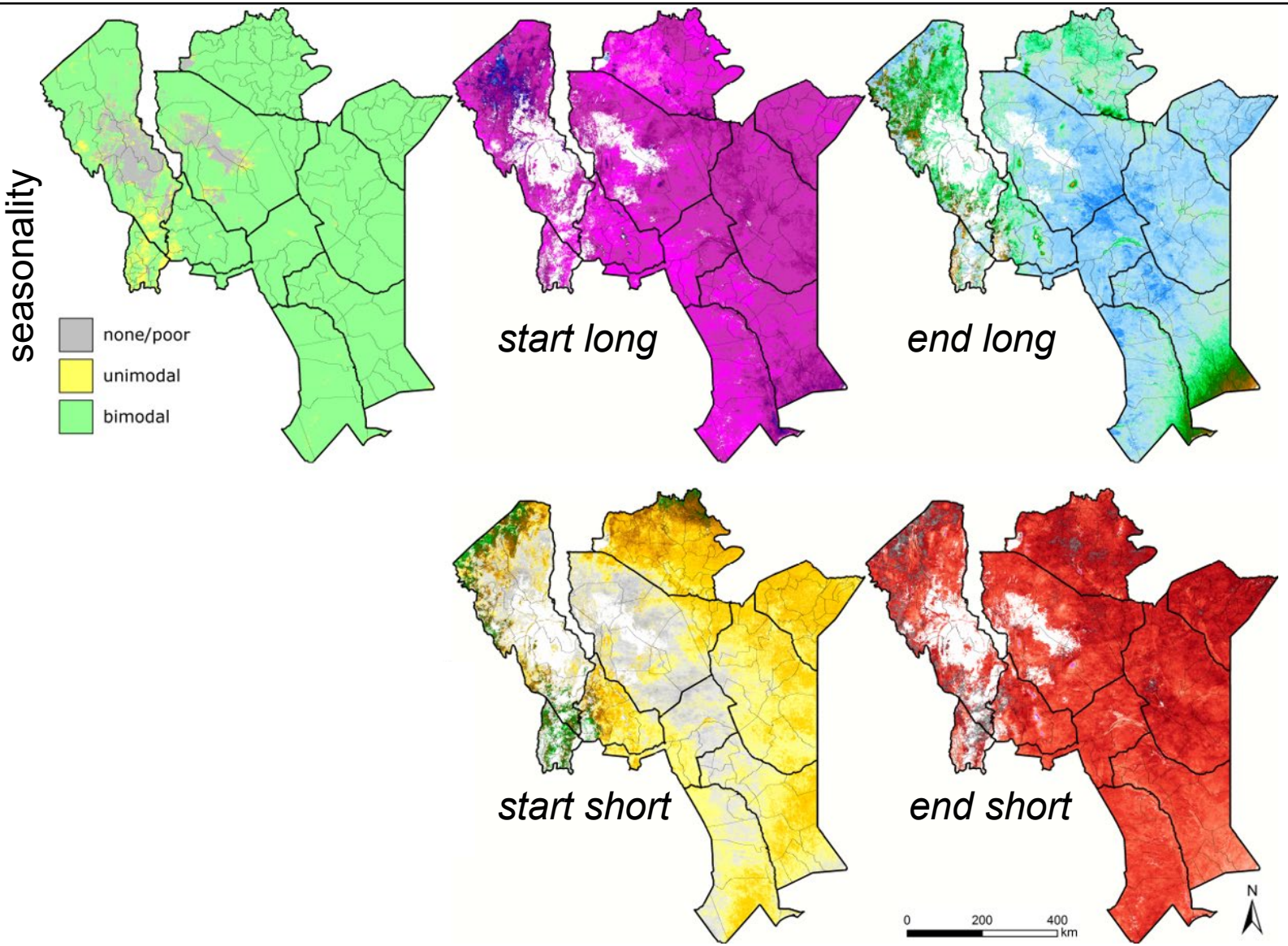




- **SOS: modelled season exceeds 20% of local growing amplitude**
- **EOS: modelled season drops below 80% of local decay amplitude**

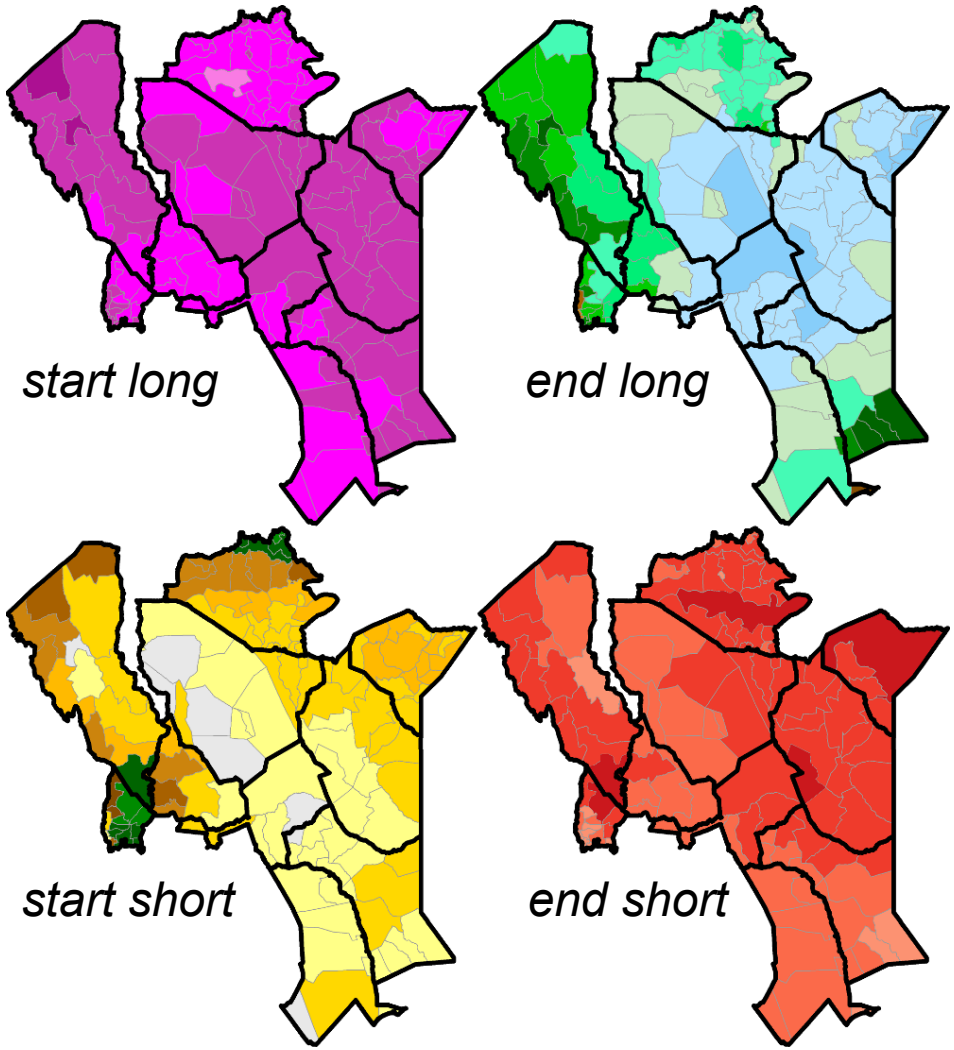
PIXEL-BASED PHENOLOGY RESULTS (2001-2014 AVERAGE)





January
February
March
April
May
June
July
August
September
October
November
December

PHENOLOGY SUMMARY PER UNIT (AVG ± 0.5 SD)



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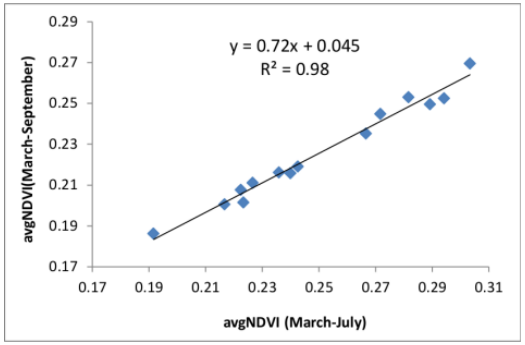
CAN WE PREDICT END-OF-SEASON VARIABILITY BEFORE?

- Take as reference identified start/end

	MAR			APR			MAY			JUN			JUL			AUG			SEP			avgNDVI
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	FULL
2001																						0.208
2002																						0.270
2003																						0.253
2004																						0.245
2005																						0.211
2006																						0.216
2007																						0.219
2008																						0.252
2009																						0.200
2010																						0.250
2011																						0.186
2012																						0.216
2013																						0.235
2014																						0.201

R^2



what is the latest end-date for which R^2 still exceeds 0.90 ?

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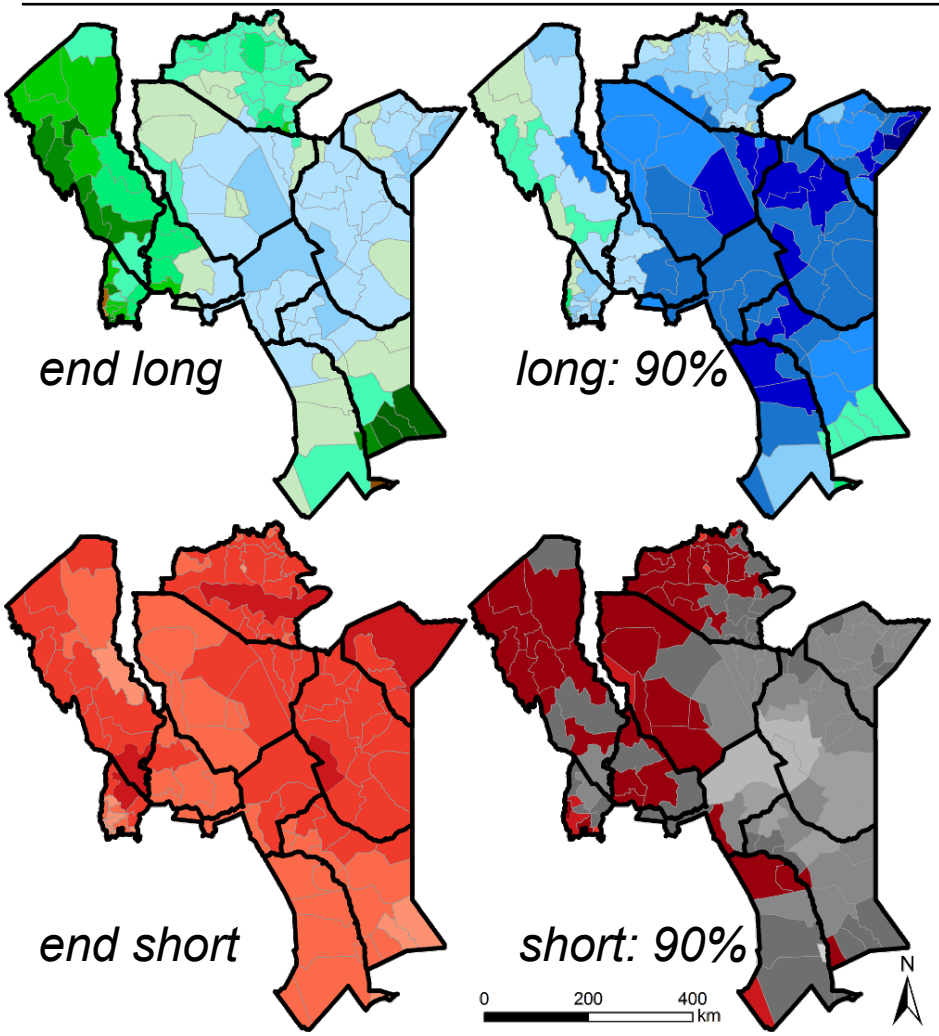
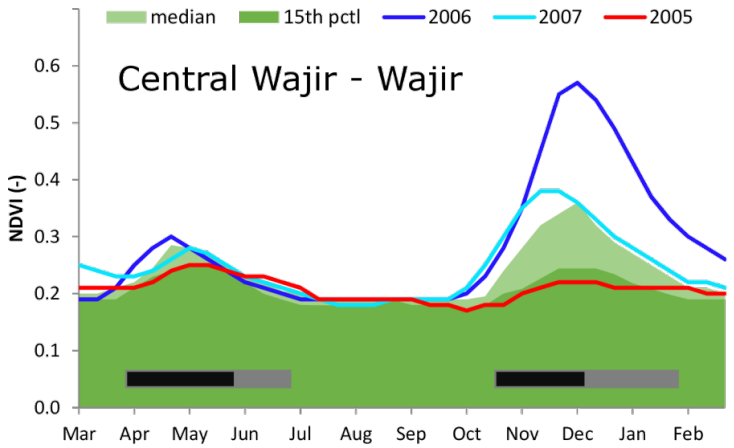
Example for Central Wajir (ID=96) but numbers are fictive

WHEN DO WE EXPLAIN 90% OF SEASON VARIABILITY?

January
February
March
April
May
June
July
August
September
October
November
December





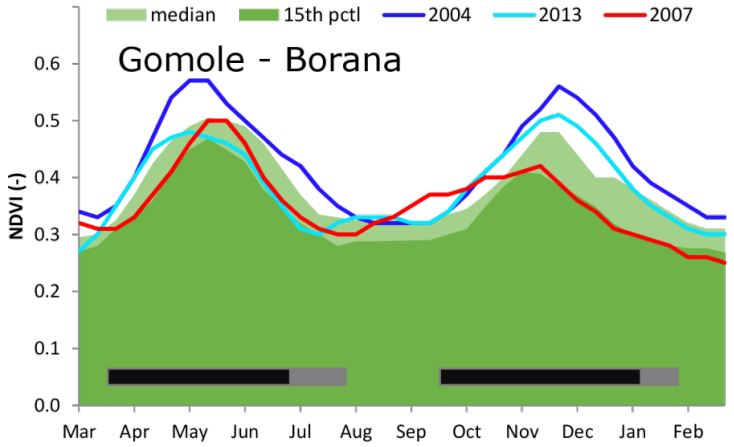
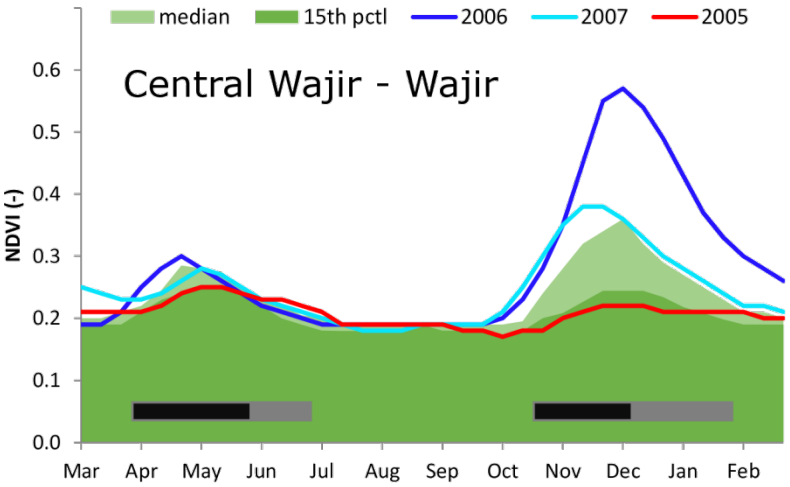
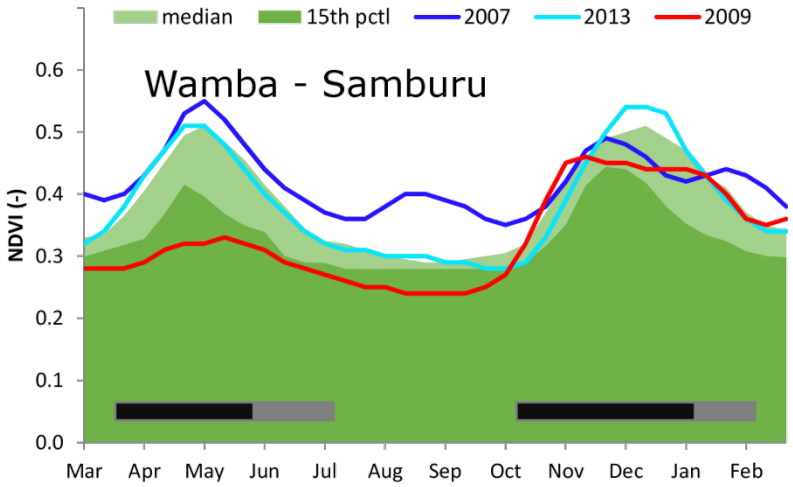
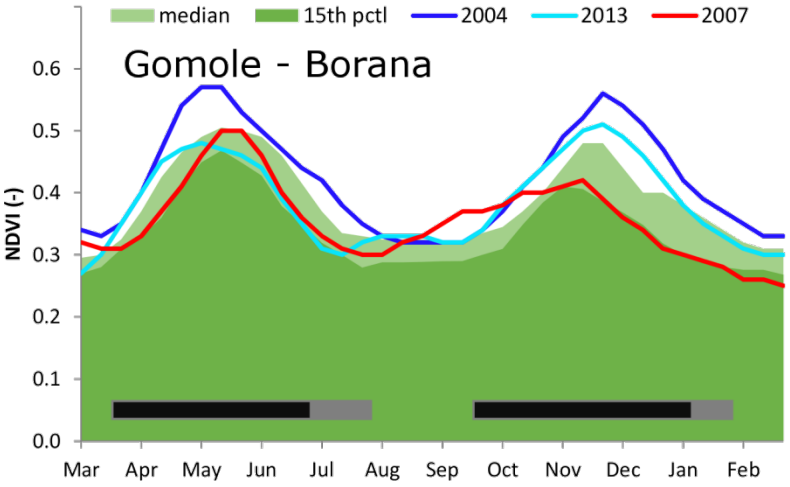
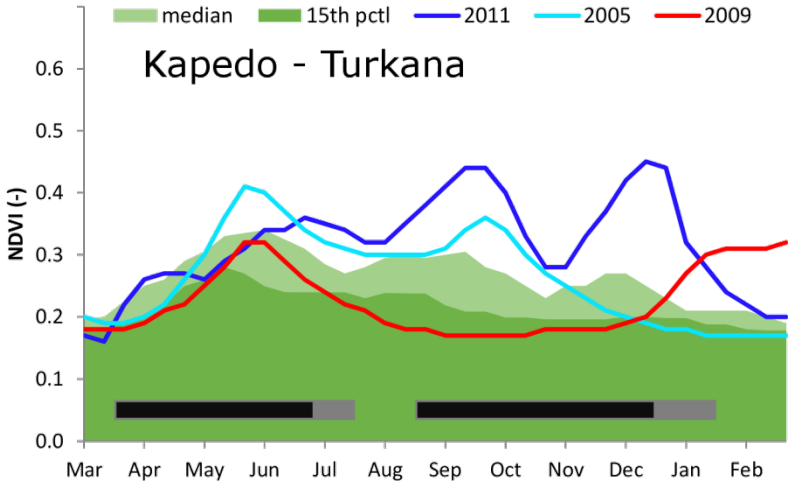


ILLUSTRATION FOR SEVERAL DIVISIONS



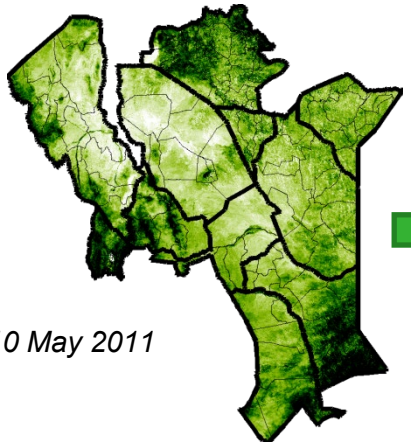






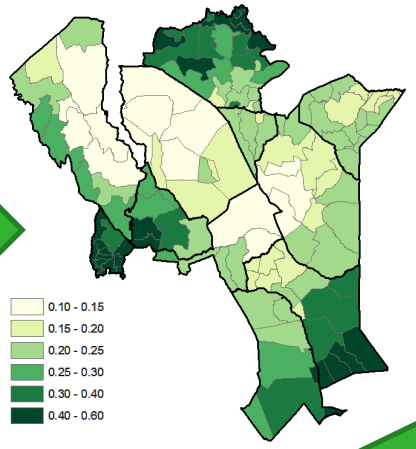
LINKING BACK TO INSURANCE

NDVI image (10 day)



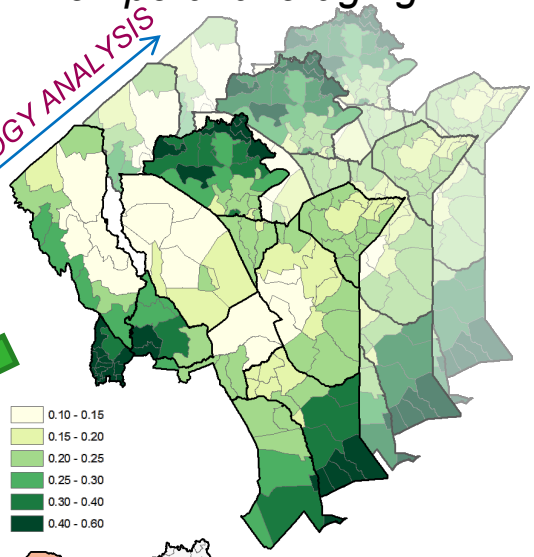
1-10 May 2011

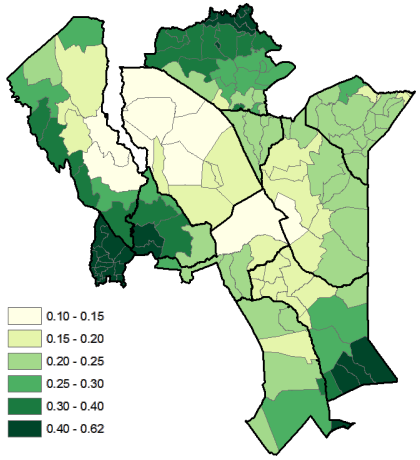
NDVI aggregated



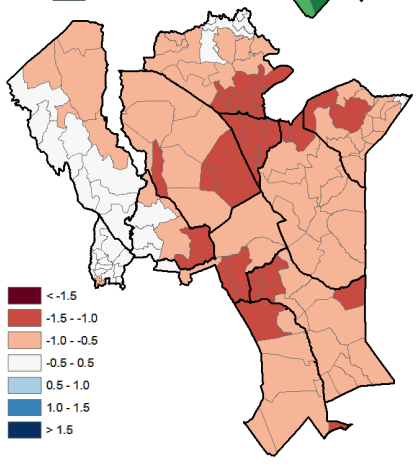
Temporal averaging

PHENOLOGY ANALYSIS





Seasonal average NDVI



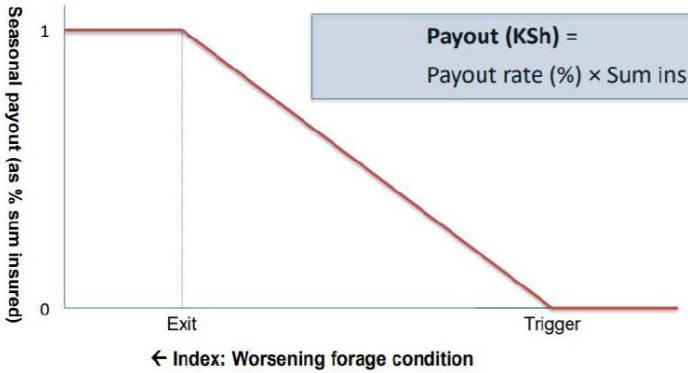
Z-scoring to get seasonal index

ITC

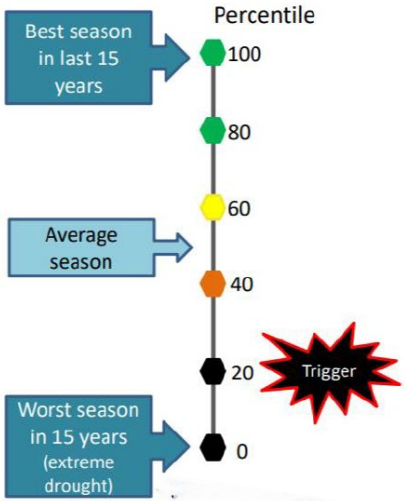
LINKING BACK TO INSURANCE

- **When and how much should the contract trigger payout?**

  - **Trigger:** The value of the NDVI Index, below which the contract will start making payouts.
  - **Exit**: The value of the NDVI Index below which 100% of the sum insured is paid out.



Payout (KSh) =
Payout rate (%) × Sum insured



theguardian

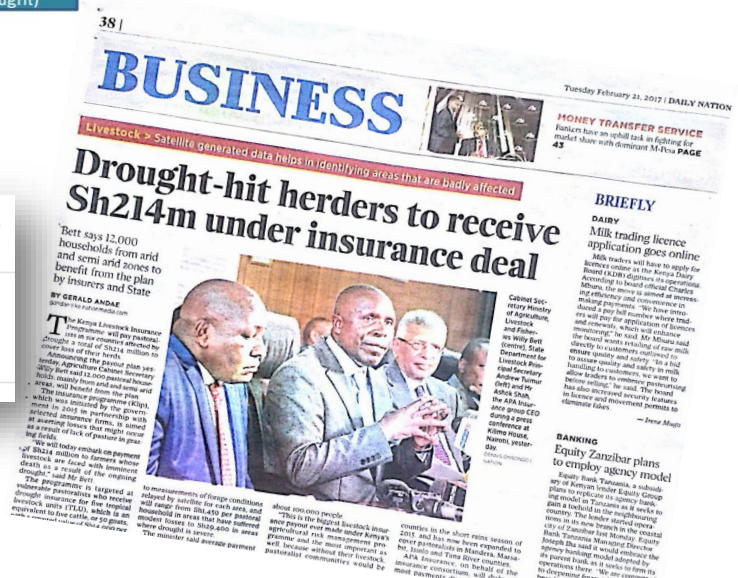
Satellite images trigger payouts for Kenyan farmers in grip of drought

Innovative insurance scheme gives a lifeline to vulnerable pastoralists, as three years of poor rains kill thousands of livestock across northern Kenya

The New York Times

Up in the Sky, Help to Keep Africans From Starving

Tina Rosenberg
FIXES NOV. 8, 2016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BUSINESS

Tuesday February 21, 2017 | DAILY NATION

MONEY TRANSFER SERVICE
Bankers have an uphill task in fighting for market share with dominant M-Pesa PAGE 43

Livestock > Satellite generated data helps in identifying areas that are badly affected

Drought-hit herders to receive Sh214m under insurance deal

BRIEFLY

DAIRY
Milk trading licence application goes online

BANKING
Equity Zanzibar plans to employ agency model

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CONCLUSIONS PHENOLOGY-INSURANCE

- Analysis of phenology helps to define “index seasons”
  - spatial variability
- Early options for indemnity payments exist (1-3 months earlier than before)
  - considering also season predictability (overall similar payout)
  - location-dependent
- This allows for protection of livestock
  - purchase of forage, water, medicines or movement livestock
- *Various types of insurance (micro, meso, macro, …)*
- VI series allow to extract useful information on seasonality of vegetation

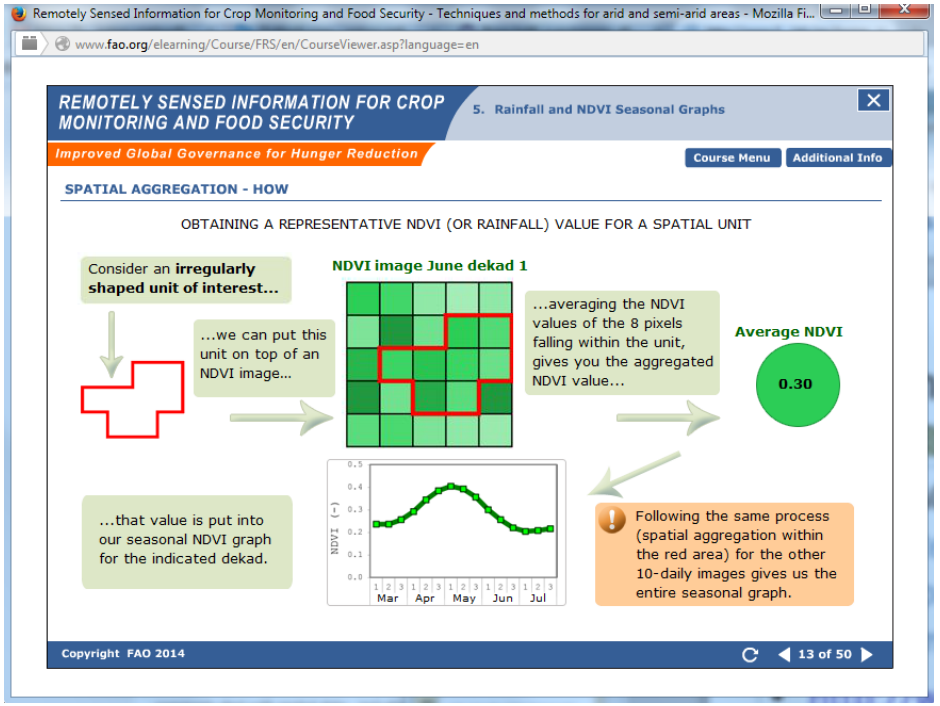
DROUGHT MONITORING BASICS: FAO E-LEARNING

- "*Remotely Sensed Information for Crop Monitoring and Food Security – Techniques and methods for arid and semi-arid areas*"
- http://www.fao.org/elearning/#/elc/en/course/FRS

1 Introduction
2 Remote Sensing Data for Crop Monitoring
3 Data Sources and Products

4 Rainfall and NDVI Anomaly Maps
5 Rainfall and NDVI Seasonal Graphs
6 Crop Status Analysis Throughout the Crop Season

7 Introduction to Yield Forecast
8 Communicating Results
9 Data Management of Remote Sensing Images
10 Required Software Functionality



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EUROPEAN COMMISSION

Fan X, A Vrieling, B Muller, A Nelson, A. 2020. Winter cover crops in Dutch maize fields: Variability in quality and its drivers assessed from multi-temporal Sentinel-2 imagery. *International Journal of Applied Earth Observation and Geoinformation*, 91, 102139

COVER CROP AFTER MAIZE IN NL (Xinyan Fan)

- Cover crop obliged after maize to reduce nitrate leaching
- NVWA (RVO) checks compliance → also satellite as input
- April 2017: student project in 3-week course
  - Finding: much variability in vegetation cover
  - How to explain variability?

- Changes in regulations
  - 6e actieprogramma nitraat 2018-'21
  - 2019 sowing cover crop before 1 October
    - or undersowing…

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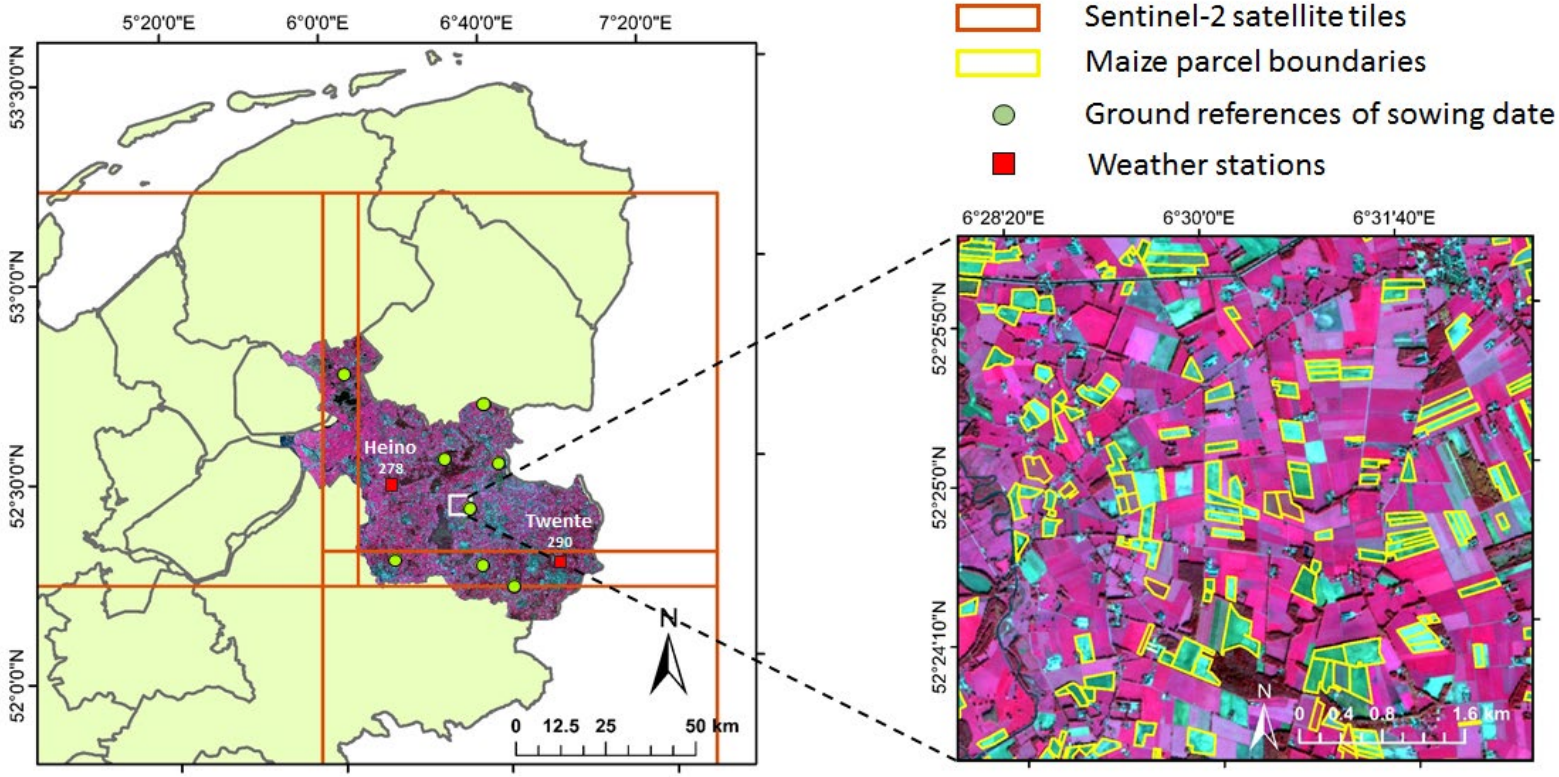
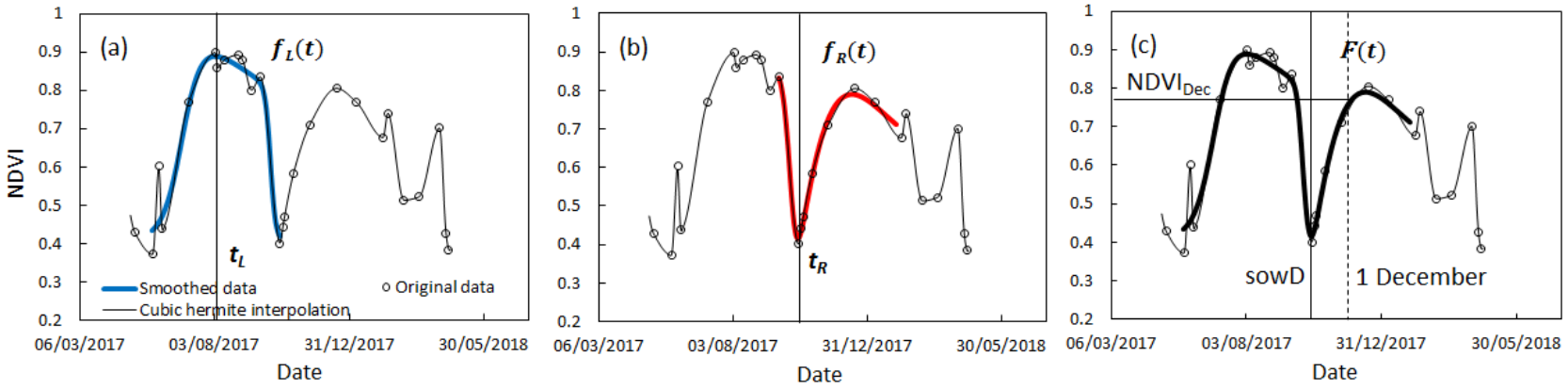
MAIZE IN OVERIJSSEL



FUNCTION FITTING ON FIELD-AVERAGE SENTINEL-2 NDVI



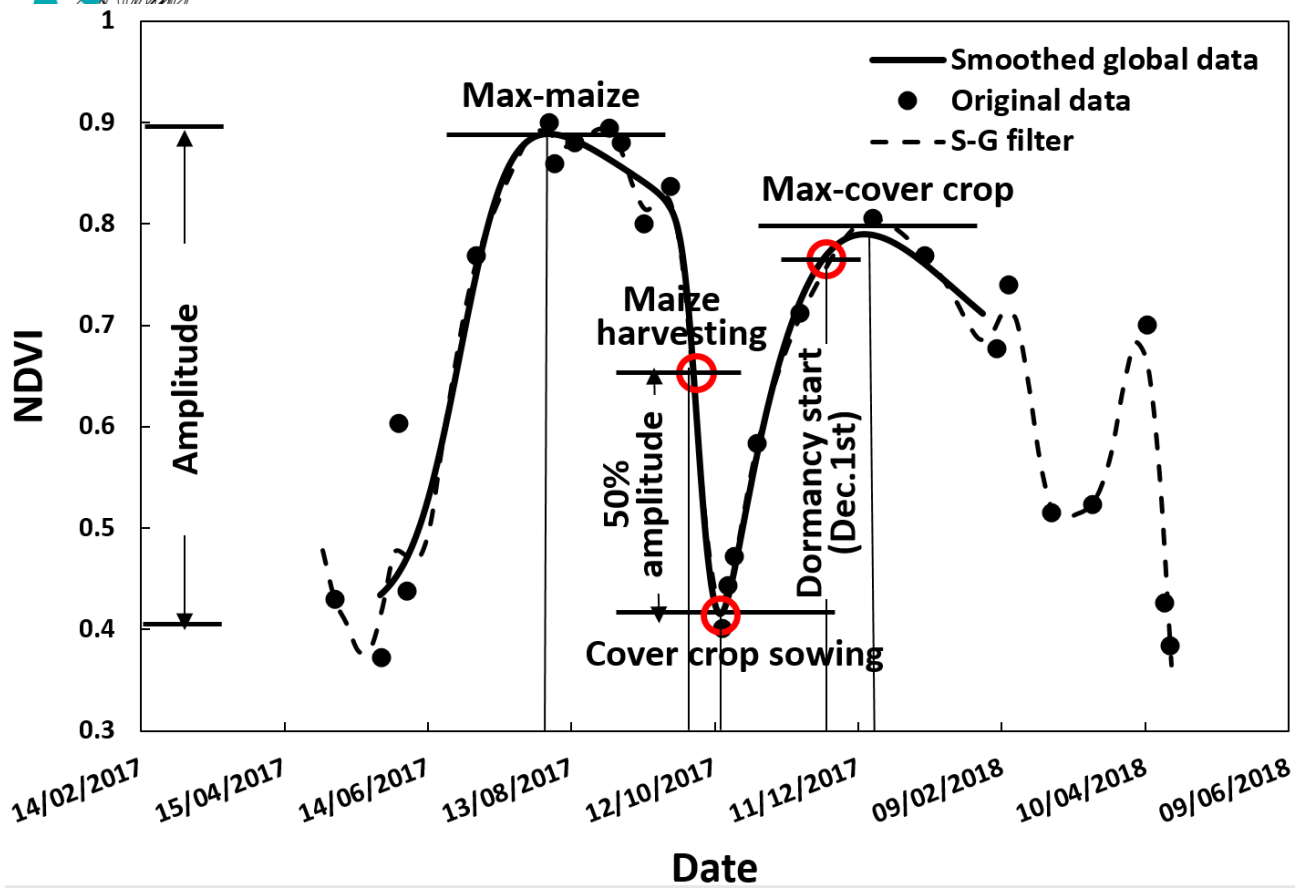
- double logistic function *(Elmore, Guinn, Minsley, & Richardson, 2012)*

$$f(t) = m_1 + (m_2 - m_7\, t)\left(\frac{1}{1 + e^{(m_3 - m_4 t)}} - \frac{1}{1 + e^{(m_5 - m_6 t)}}\right)$$

- Weighting of two functions:

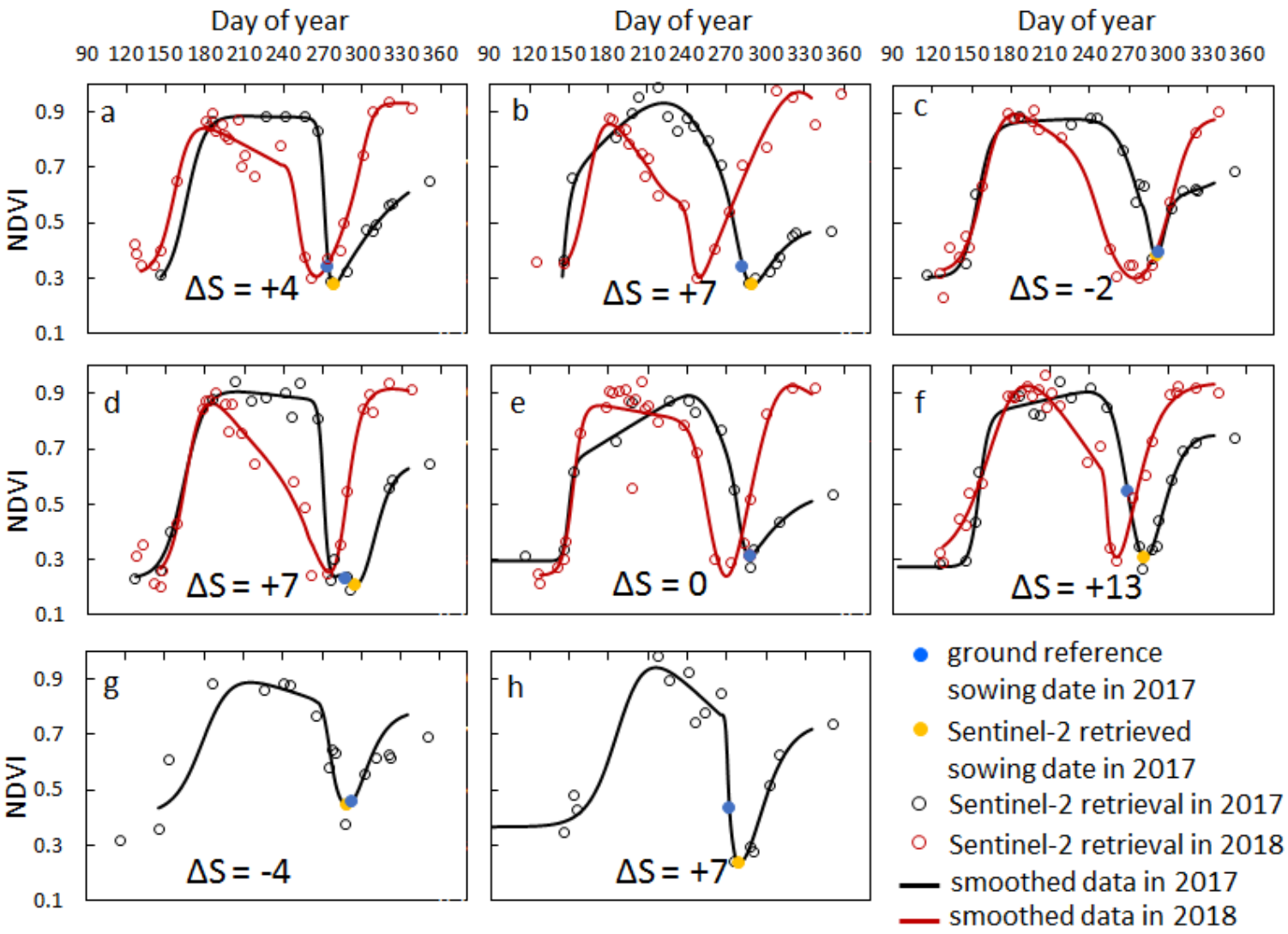
$$F(t) = \alpha(t) f_L(t) + \big(1 - \alpha(t)\big) f_R(t) \qquad t_L < t < t_R$$

RETRIEVAL OF PARAMETERS FROM SENTINEL-2 NDVI

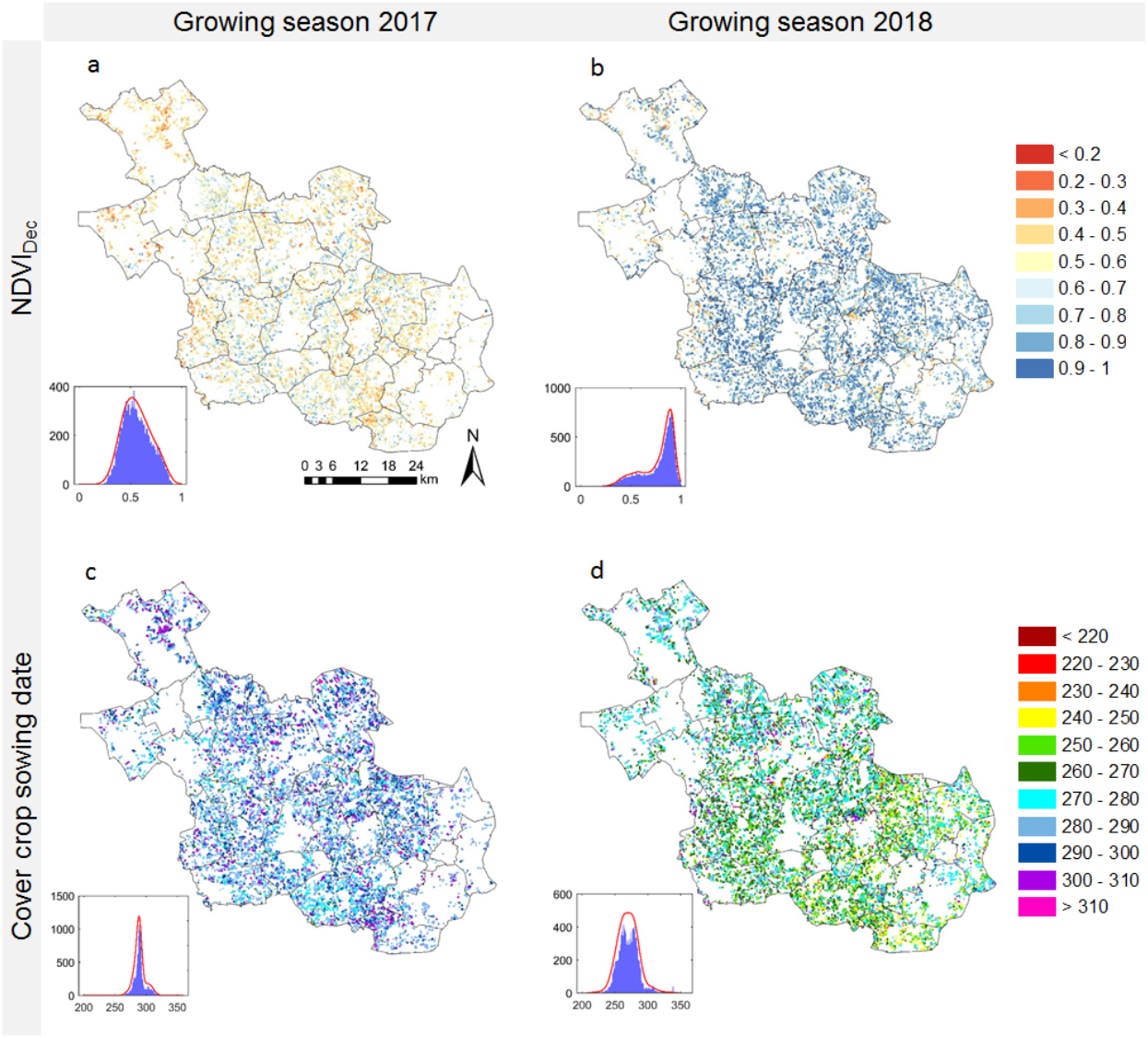


- Maize harvesting date: 50% amplitude
- Cover crop sowing: inflexion point
- Max-NDVI value of cover crop
- NDVI value on 1 Dec.

COMPARISON WITH FIELD DATA (NOTE ALSO DIFFERENCE 2017-2018!)



FIELD-BASED ASSESSMENT OF PARAMETERS



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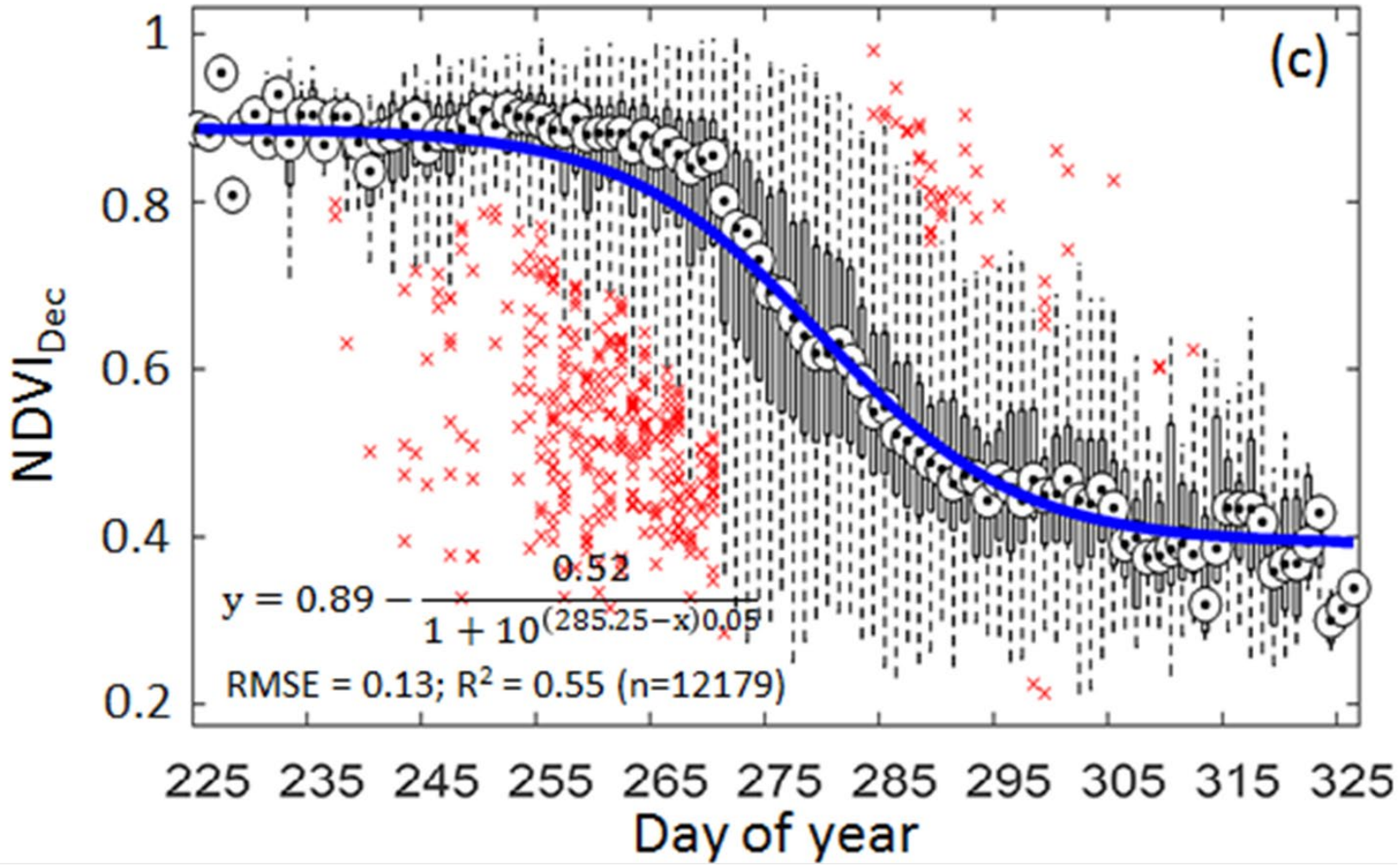
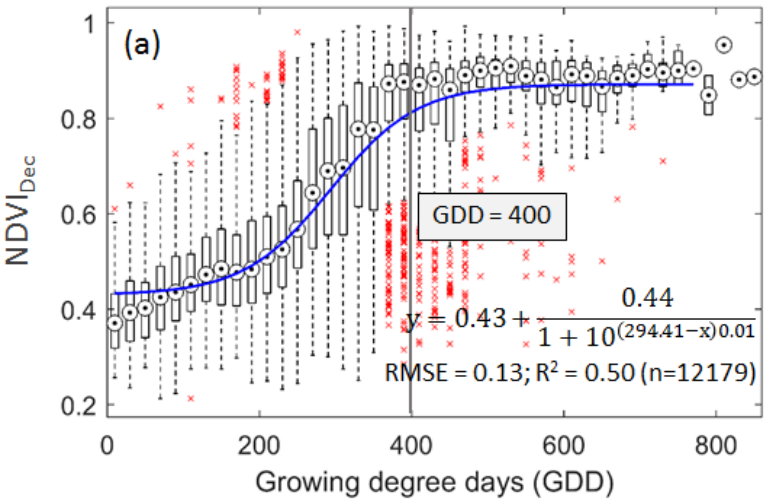
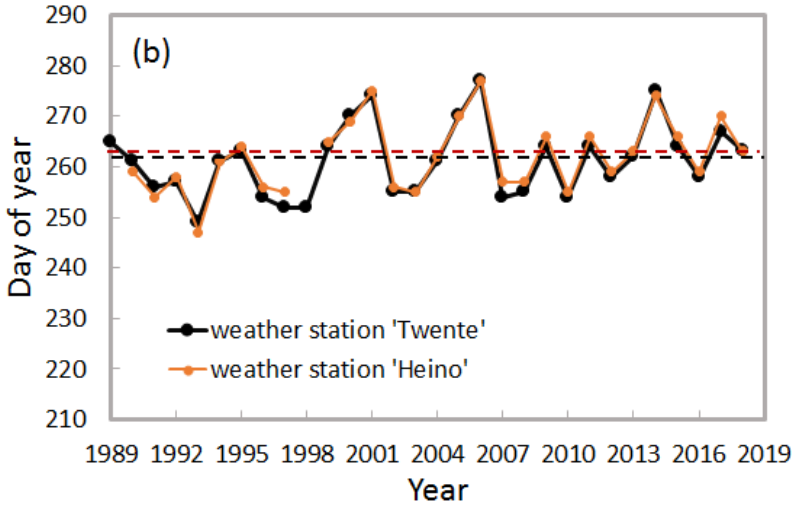
EFFECT SOWING DATE ON PERFORMANCE (ALL FIELDS, BOTH YEARS)



LINKING TO A GDD MODEL





- $GDD = \max\left(\left(\frac{T_{max}+T_{min}}{2} - T_{base}\right), 0\right)$
- Calculate backwards: what should have been the sowing date if by 1 Dec 400 GDD should have been reached?

CONCLUSIONS COVER CROP

- Sentinel-2 time series effective to study vegetation changes on individual plots
- Large variability of winter ground cover for cover crops
  - Later sowing dates can explain part of poorer performance
  - Positive correlation with GDD
    - Past 30 years, average ‘ideal’ sowing date: 19-Sep (±7days)
    - As maize ripening is often later (and requirement sowing cover crop by 1 October from 2019) → undersowing

https://www.verantwoordeveehouderij.nl/show/Demonstratie-Onderzaai-gras-in-mais-1.htm